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Use of condensed tannin extract from quebracho trees to reduce methane emissions from cattle[1]

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ABSTRACT: Our objective was to determine if condensed tannin extract from quebracho trees (*Schinopsis quebracho-colorado;* red quebracho) could be used to reduce enteric methane emissions from cattle. The experiment was designed as a repeated 3 × 3 Latin square (4 squares) with 3 treatments (0, 1, and 2% of dietary DM as quebracho tannin extract) and 3 28-d periods. Six spayed Angus heifers (238 ± 13.3 kg of initial BW) and 6 Angus steers (207 ± 8.2 kg of initial BW) were each assigned to 2 squares. The measured condensed tannin content of the extract was 91%, and the basal diet contained 70% forage (DM basis). Feeding quebracho tannin extract had no effect on BW, ADG, or nutrient intakes. Furthermore, it had no effect on DM, energy, or fiber (ADF and NDF) digestibility, but apparent digestibility of CP decreased linearly ($P < 0.001$) by 5 and 15% with 1 and 2% quebracho tannin extract, respectively. There were no effects of quebracho tannin extract on methane emissions (g/d, g/kg of DM, % of GE intake, or % of DE intake). Feeding up to 2% of the dietary DM as quebracho tannin extract failed to reduce enteric methane emissions from growing cattle, although the protein-binding effect of the quebracho tannin extract was evident.

Key words: beef cattle, condensed tannin, greenhouse gas, methane

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INTRODUCTION

There is growing worldwide interest in reducing the potential for global warming by reducing emissions of greenhouse gases into the atmosphere (IPCC, 2006). Methane is a potent greenhouse gas, of which approximately 15% of the global emissions are from enteric methane produced by domestic ruminants (IPCC, 2001). A 25% reduction in methane emissions could also increase BW gain of growing cattle by approximately 75 g/d or milk production of dairy cows by 1 L/d, based on the energy balances reported by Bruinenberg et al. (2002) and Nkrumah et al. (2006).

Some feed additives, and in particular condensed tannins, can reduce enteric methane emissions from ruminants, but further research is necessary before these compounds can be recommended for widespread use (Boadi et al., 2004). Condensed tannins, or proanthocyanidins, are a diverse group of polymeric flavanoids that readily complex with carbohydrates and proteins (Hagerman, 1992). Consequently, the tannin-protein reaction has been widely used to improve protein metabolism in ruminants (Aerts et al., 1999).

Recently, many studies have reported that feeding tannin-containing forages to ruminants may reduce methane emissions (Pinares-Patiño et al., 2003; Woodward et al., 2004; Puchala et al., 2005). However, in most of those studies, the reduction in methane was confounded with changes in forage quality. Furthermore, tannin-rich forages are not agronomically suited to all conditions and, thus, may not be readily available.

A concentrated source of condensed tannins may be a possible alternative approach to feeding tannin-rich forages to reduce methane emissions. Recently, Carulla et al. (2005) reported that feeding *Acacia mearnsii* (black wattle tree) extract (2.5% of DMI) to sheep decreased methane per kilogram of intake by approximately 12%. Whether condensed tannins from other sources also reduce methane emissions, and the dietary concentration of condensed tannins necessary for such a reduction, is not clear.

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The objective of our study was to determine if supplementing a forage-based diet with tannin extract (up to 2% of dietary DM) from quebracho trees (*Schinopsis quebracho-colorado;* red quebracho) could be used to reduce enteric methane emissions from cattle while having little effect on intake and digestibility.

MATERIALS AND METHODS

Experimental Design, Animals, and Treatments

The experiment was conducted in accordance with the guidelines of the Canadian Council on Animal Care (1993) and was approved by the animal care committee of the Lethbridge Research Centre. The experiment was designed as a repeated 3 × 3 Latin square, with 2 groups assigned to 4 squares, 3 treatments, and three 28-d periods. Six spayed Angus heifers (238 ± 13.3 kg of initial BW) were allocated to group 1 (2 squares), and 6 Angus steers (207 ± 8.2 kg of initial BW) were allocated to group 2 (2 squares). The cattle were approximately 6- to 8-mo old and were adapted beforehand to being handled within the facilities. Within each group, 2 cattle were fed (1/square) each treatment. During the methane measurements, the cattle were housed 2/chamber; thus, the experimental design for methane measurements was a double 3 × 3 Latin square with 2 cattle/cell.

The treatments were quebracho tannin extract supplemented at 0, 1, and 2% of dietary DM. The extract was purchased commercially (Unitan Saica, Chaco, Argentina) as a powder, with a guaranteed minimum of 90% condensed tannins. The condensed tannin content of the extract was 91%, as measured using the butanol-HCl procedure of Terrill et al. (1992). The appropriate quantity of quebracho tannin extract for each animal was weighed daily, suspended in 500 mL of warm water, poured onto the feed, and mixed into the feed by hand.

Diet and Animal Management

The basal diet consisted of approximately 70% forage (Table 1). The diet contained 16% CP (DM basis) and was formulated using the NRC (1996) to meet or exceed the NE, mineral, and vitamin requirements of cattle gaining 0.7 kg/d. The ration was prepared daily using a feed mixer (Data Ranger, American Calan Inc., Northwood, NH), and feed was offered once daily for ad libitum consumption (at least 10% orts). Quantities of feed offered and refused were recorded daily for each animal for the entire experiment, and samples of the diet and refusals were retained weekly for determination of DM content. Ad libitum DMI was calculated for each animal based on the first 23 d of the period, before the cattle were moved to the chambers for methane measurement.

From d 1 to 23 of each period, cattle were housed in a heated barn in individual tie stalls equipped with a feeder and water bowl. Daily feed intake, total tract digestibility, and ruminal fermentation were measured in this facility. The groups were offset by 1 wk to facilitate measurements. Near the end of each experimental period, a group was moved to 3 environmental chambers (2 cattle/chamber) to measure methane emissions continuously for 72 h, as described in a following section. The cattle were weighed at the beginning of the experiment (not fasted beforehand) and at the end of each period to determine mean BW and ADG for each period.

Table 1. Ingredient and analyzed composition of the basal diet

Ingredient[1]	DM, %
Barley silage[2]	69.44
Barley grain, steam-rolled	15.94
Barley grain, ground	5.47
Soybean meal	3.42
Corn gluten meal	3.42
Calcium carbonate	1.14
Salt	0.68
Dicalcium phosphate	0.23
Dried molasses	0.15
Canola oil	0.06
Mineral and vitamin premix[3]	0.05
Analyzed composition	
DM, %	44.3 ± 2.1[4]
GE, Mcal/kg of DM	4.24 ± 0.060
CP, % of DM	16.0 ± 0.21
ADIN, % of CP	29.9 ± 2.5
NDF, % of DM	45.1 ± 2.2
ADF, % of DM	26.1 ± 1.0

[1]All ingredients except for steam-rolled barley and silage were provided as part of a supplement.
[2]Composition (DM basis) of the barley silage was 4.11 ± 0.053 Mcal of GE/kg, 11.7 ± 1.0% CP, 39.4 ± 8.5% of CP as ADIN, 53.8 ± 5.1% NDF, and 32.7 ± 4.1% ADF.
[3]Formulated to supply the following per kilogram of dietary DM: 65 mg of Zn, 28 mg of Mn, 15 mg of Cu, 0.30 mg of Se, 0.2 mg of Co, 0.7 mg of I, 6,000 IU of vitamin A, 600 IU of vitamin D, and 14 IU of vitamin E.
[4]Mean ± SD; n = 4.

Ruminal Fermentation Measurements

Samples of ruminal fluid were obtained 2 h after feeding on d 21 of each period. A metal speculum was inserted into the mouth, and a lubricated 3.6-m rubber tube was inserted through the speculum into the rumen via the esophagus. Ruminal contents (200 mL) were removed using a vacuum pump (model DD195, Precision Scientific, Niagara Falls, NY). Samples were monitored visually to ensure they did not contain saliva. Whole ruminal contents were squeezed through 4 layers of cheesecloth. Filtrate (10 mL) was preserved for VFA analysis by adding 2 mL of 25% (wt/vol) HPO_3 and for NH_3 analysis by adding 2 mL of 0.18 *M* H_2SO_4.

Apparent Digestibility

Total tract digestibility of nutrients was determined using an external marker prepared from chromic oxide

(27.3%), ground barley (66.2%), and canola oil (6.5%). Ten grams of marker, providing approximately 1.87 g of Cr, was top-dressed once daily onto the feed of individual cattle for 10 consecutive days of each period (d 12 to 21). Invariably, the entire allotment of marker was consumed. Fecal samples (100 g of wet weight) were collected from the rectum of each animal on the last 4 d of marker dosing (d 17 to 21). Samples were taken twice daily, at various times throughout the day, to account for possible temporal fluctuations in Cr concentration. The samples were pooled by day for each animal within period and frozen immediately (–20°C). The samples were later dried at 55°C for 48 h in a forced-air oven, ground through a 1-mm screen, and analyzed for DM, GE, NDF, ADF, ADIN, and Cr, as described in a following section. Chromium was assumed to be unabsorbed, and the digestibility of the DM was calculated for each day of fecal collection as follows: DM digestibility = $(1 - \{[\text{Cr fed (mg/d)}]/[\text{DMI (kg/d)} \times \text{Cr in feces (mg/kg of DM)}]\}) \times 100$. Digestibility of GE, CP, NDF, ADF, and ADIN was calculated using the same approach.

Methane Emissions

Cattle were moved to 3 environmental chambers in a separate facility on d 24 of each period to measure methane emissions. Cattle had been conditioned to the environmental chambers before beginning the experiment to minimize stress while in the chambers. Within each group, the 2 cattle on the same treatment were housed together within a chamber. The same pairing was maintained throughout the experiment. Methane concentration was monitored for 3 consecutive days beginning approximately 12 h after the cattle were put into the chambers.

The 3 chambers measured 4.4-m wide × 3.7-m deep × 3.9-m tall (63.5-m^3 volume; C1330, Conviron Inc., Winnipeg, Manitoba, Canada). Within the chambers, the cattle were housed in individual raised stalls that were equipped with individual feeders. Each chamber was vented using a fresh-air intake and exhaust duct, with dedicated fans on each duct. Airflow, corrected for air velocity and temperature (model 8330, TSI Inc., Shoreview, MN), was monitored continuously within each duct. Flow rates of the intake and exhaust ducts generated a small positive pressure (<2 Pa) inside the chamber to prevent any possible leaks into the chambers, and the air volume within the chamber was exchanged every 5 min.

Methane concentrations in the intake and exhaust air ducts were monitored using a methane analyzer (model Ultramat 5E, Siemens Inc., Karlsruhe, Germany). The difference between the incoming and outgoing mass of methane was used to calculate the amount generated in each chamber by the 2 cattle.

The chamber doors were opened once daily for feeding and cleaning, and the corresponding fluxes were omitted. These daily interruptions had little effect on the daily emissions, because the time constant (i.e., the time required for methane concentrations to reach steady state) for the chambers was less than 10 min.

Before beginning the experiment, the chambers were calibrated by releasing known amounts of methane into each empty chamber and calculating the recovery. A 3-point regression was developed for each chamber by releasing 0, 0.2, and 0.4 L/min of methane sequentially. Calibration factors (i.e., factors to adjust each chamber to 100% recovery) were then used to correct chamber methane emission data from the experiment. A full description of the chambers and methods used to calculate the daily methane emissions are given by Beauchemin and McGinn (2005).

Laboratory Analyses

Analyses were performed on each sample in duplicate, and where the CV was > 5%, the analysis was repeated. Analytical DM was determined by drying the oven-dried samples at 135°C for 2 h, followed by hot weighing (AOAC, 1995; method 930.05). Gross energy was determined using an adiabatic calorimeter (model 1241, Parr, Moline, IL). The NDF was determined, as described by Van Soest et al. (1991), using heat-stable α-amylase and sodium sulfite, and ADF was determined according to procedures of the AOAC (1995; method 973.18). For the measurement of CP (N × 6.25), samples were ground to a fine powder using a ball mill (Mixer Mill MM2000, Retsch, Haan, Germany). Nitrogen was quantified by flash combustion with gas chromatography and thermal conductivity detection (Carlo Erba Instruments, Milan, Italy). The ADIN fraction was determined by measuring the N content of the acid detergent residue after ADF analysis. Chromium was determined by inductively coupled plasma emission spectrometry (SpectoCiros^{CCD}, Specto Analytical Instruments, GmbH & Co., Kleve, Germany) after dry ashing and extraction with H_3PO_4, $MnSO_4$, and $KBrO_3$. Ruminal VFA were separated and quantified by GC (Varian 3700, Varian Specialties Ltd., Brockville, Ontario, Canada) using a 15-m (0.53-mm i.d.) fused silica column (DB-FFAP column, J & W Scientific, Folsom, CA). Ruminal NH_3 was determined using the method described by Weatherburn (1967) that was modified to use a plate reader.

Calculations and Statistical Analyses

Cattle were the experimental units for all variables, except methane, because these data were obtained from individual cattle with separate access to feed. A mixed model (SAS Institute Inc., Cary, NC) that included the fixed effects of group (heifers vs. steers), treatment (0, 1, or 2% quebracho tannin extract), and the group × treatment interaction was used. Period within group and animal within group were considered random effects. Day was considered a repeated measure for the ad libitum intake and digestibility variables.

Table 2. Body weight, ADG, and intake of growing beef cattle fed a forage-based diet supplemented with quebracho tannin extract

	Quebracho tannin extract, % of dietary DM				*P*-value	
Item	0	1	2	SEM[1]	Linear	Quadratic
Mean BW, kg	255	254	255	11	0.90	0.23
ADG, kg/d	0.81	0.82	0.76	0.086	0.42	0.54
Nutrient intake						
DM, % of BW	2.23	2.24	2.22	0.075	0.71	0.54
DM, kg/d	5.68	5.72	5.67	0.29	0.95	0.46
GE, Mcal/d	24.0	24.0	24.0	1.3	0.89	0.42
CP, kg/d	0.91	0.92	0.92	0.047	0.77	0.53
NDF, kg/d	2.55	2.56	2.54	0.14	0.96	0.65
ADF, kg/d	1.45	1.46	1.45	0.069	0.94	0.37
ADIN, kg/d	0.28	0.28	0.28	0.008	0.76	0.61

[1]n = 12.

For methane emissions, the experimental unit was the chamber. The daily methane flux determined for each chamber was expressed by DMI, GE intake, and DE intake of the paired cattle within the chamber on that day. The mixed model included the fixed effect of group, treatment, and their interaction, with the random effects of period within group and chamber within group. Day of measurement was considered a repeated measure.

The REML method was used for estimating the variance components, and df were adjusted using the Kenward-Roger's option. The variance-covariance error structure was compound symmetry, because it gave the lowest Akaike information criterion values. Main effects were considered different when $P < 0.05$. Treatment means were examined for linear and quadratic effects using orthogonal contrasts.

RESULTS

There were no interactions between the effects of sex and quebracho tannin extract, except for butyrate concentration ($P = 0.02$). Thus, only means for the main effect of treatment are presented. Feeding quebracho tannin extract had no effect ($P \geq 0.47$) on BW, ADG, or nutrient intakes (Table 2).

Adding quebracho tannin extract to the diet had no effect ($P \geq 0.38$) on DM, energy, ADF, or NDF digestibility (Table 3). Because of the lack of effects of quebracho tannin extract on intake and digestibility of DM and energy, there was no effect ($P \geq 0.44$) of quebracho tannin extract on intake of digestible DM or DE. However, quebracho tannin extract linearly decreased ($P < 0.001$) the apparent digestibility of CP and ADIN. Digestibility of CP decreased by 5 and 15%, with 1 and 2% quebracho tannin extract, whereas digestibility of ADIN decreased by 43 and 93%, respectively.

Despite a lack of effect of quebracho tannin extract on total tract digestibility of DM, increasing levels of supplementation tended to linearly decrease ($P = 0.08$) total VFA concentration (Table 4). In addition, quebracho tannin extract linearly decreased ($P = 0.004$) the proportion of acetate, which linearly decreased ($P = 0.03$) the acetate:propionate ratio. Similarly, ruminal NH_3 concentrations decreased ($P = 0.03$) with increasing level of quebracho tannin extract.

There were no effects ($P = 0.37$) of quebracho tannin extract supplementation on methane emissions, regardless of how emission was expressed (Table 5). Methane production, expressed as a percentage of GE intake, averaged 5.6% (SD = 1.2) for the study.

DISCUSSION

Feeding up to 2% of the dietary DM as quebracho tannin extract failed to reduce enteric methane emissions from growing cattle, although the protein-binding effect of the condensed tannins was evident. The quebracho tannin extract used in this study contained a high percentage (91%) of condensed tannins; thus, the actual levels of condensed tannin supplementation were 0, 0.9, and 1.8% of DM. A reduction in enteric methane emissions was expected, at least at the highest level of supplementation, based on the study by Carulla et al. (2005) that reported reduced methane emissions from sheep when fed a condensed tannin extract from *A. mearnsii*. In that study, supplementing the diet with 2.5% condensed tannins decreased methane production by approximately 12%, due in part to a 5% reduction in the total tract NDF digestion. To minimize negative effects of condensed tannins on fiber digestibility, a slightly lower level of supplementation was used in our study compared with that of Carulla et al. (2005).

Various other studies have reported that feeding condensed tannin-containing forages to ruminants reduces methane emissions (Waghorn et al., 2002; Woodward et al., 2002, 2004; Pinares-Patiño et al., 2003; Puchala et al., 2005). The tannin-containing forages used in those studies include sulla (*Hedysarum coronarium,* 2.7 to 6.8% condensed tannins), red clover (*Trifolium pretense,* 0.3% condensed tannins), big trefoil (*Lotus pedunculatus,* 5.3% condensed tannins), and Sericea

Table 3. Apparent total tract digestibility of a forage-based diet supplemented with quebracho tannin extract and fed to growing beef cattle

	Quebracho tannin extract, % of dietary DM				*P*-value	
Item	0	1	2	SEM[1]	Linear	Quadratic
Digestibility, %						
DM	60.9	61.3	60.1	1.7	0.59	0.57
GE	59.2	59.4	57.8	1.5	0.38	0.53
CP	63.4	60.0	54.5	1.7	<0.001	0.35
NDF	47.1	47.5	46.8	2.6	0.88	0.78
ADF	39.8	37.6	35.8	3.4	0.17	0.94
ADIN	41.6	23.7	2.8	6.7	<0.001	0.62
Intake						
Digestible DM, kg/d	3.51	3.59	3.48	0.15	0.81	0.31
DE, Mcal/d	14.5	14.8	14.2	0.57	0.53	0.28

[1]n = 12.

lespedeza (*Lespedeza cuneata,* 17.7% condensed tannins). However, in most of those studies, the reduction in methane due to feeding forages containing condensed tannins was confounded with changes in forage quality, such as lower NDF content. For example, in the study by Woodward et al. (2002), methane emissions from lactating dairy cows were lower for cows grazing sulla pastures than perennial ryegrass pastures (6.1 vs. 7.2% of GE intake), but the NDF content of sulla was considerably lower than that of the ryegrass (14.7 vs. 48.3% of DM). Because lower-fiber diets are associated with lower methane emissions (Johnson and Johnson, 1995), the methane reduction in that study may have been due to a change in nutrient composition. Thus, there is still considerable uncertainty about the effectiveness of condensed tannin extracts and condensed tannin-containing forages to reduce enteric methane emissions from cattle.

Tavendale et al. (2005) proposed 2 mechanisms whereby condensed tannins reduce methane emissions from ruminants: 1) indirectly through a reduction in fiber digestion, which decreases H_2 production, and 2) directly through an inhibition of the growth of methanogens. In our study, the lack of effect of quebracho tannin extract supplementation on methane production was consistent with the lack of effect on total tract DM and fiber digestibility. Despite the lack of effects of quebracho tannin extract on total tract digestibility, the linear reduction in total VFA concentration with increasing level of quebracho tannin extract supplementation, together with linear reduction in acetate:propionate ratio, suggests some changes in ruminal fermentation as a result of dietary inclusion of tannins. We did not examine the direct effects of the quebracho tannin extract on rumen bacterial populations, but direct effects on methanogens were unlikely given the lack of effect of the quebracho tannin extract on methane emissions.

Condensed tannins extracted from different plants vary greatly in their capacity to bind carbohydrates and proteins (McAllister et al., 2005). Thus, it is possible that quebracho tannin extract is a less effective methane suppressant than other condensed tannin sources, such as *A. mearnsii* used by Carulla et al. (2005). The effect of condensed tannins on microbial populations depends on the relative affinity of condensed tannins for feed vs. microbial protein. The affinity of condensed

Table 4. Ruminal characteristics of growing beef cattle fed a forage-based diet supplemented with quebracho tannin extract

	Quebracho tannin extract, % of dietary DM				*P*-value	
Item	0	1	2	SEM[1]	Linear	Quadratic
Total VFA, m*M*	108.8	100.3	100.4	4.6	0.08	0.29
VFA, mol/100 mol						
Acetate	65.8	65.4	64.6	0.69	0.004	0.50
Propionate	19.0	19.0	19.6	0.55	0.17	0.36
Butyrate	10.5	10.4	10.6	0.58	0.69	0.78
Isobutyrate	1.03	1.05	1.03	0.038	0.88	0.53
Isovalerate	1.81	1.89	1.92	0.084	0.32	0.81
Acetate:propionate	3.50	3.47	3.31	0.12	0.03	0.37
NH_3, m*M*	10.35	9.39	9.08	0.81	0.03	0.50

[1]n = 12.

Table 5. Methane emissions from growing beef cattle fed a forage-based diet supplemented with quebracho tannin extract

Methane emission	Quebracho tannin extract, % of dietary DM				*P*-value	
	0	1	2	SEM[1]	Linear	Quadratic
g/d	98.7	99.1	99.7	9.4	0.75	0.85
g/kg of DMI	18.82	18.51	18.79	1.7	0.97	0.62
% of GE intake	5.61	5.90	5.45	0.57	0.68	0.30
% of DE intake	9.57	10.46	9.29	1.2	0.74	0.19

[1]n = 6.

tannins for protozoa and methanogens may be particularly important due to the symbiotic role these populations have on methane production (McAllister et al., 1996). In our experiment, the decline in the apparent digestibility of protein in the absence of a change in methane production suggests that the condensed tannins in quebracho may have a greater affinity for feed protein than for microbial protein. It is also possible, but unlikely, that the response to condensed tannins differs between cattle and sheep. Although goats are less susceptible to condensed tannin-containing plants than sheep and cattle (Puchala et al., 2005), sheep and cattle are expected to react similarly, because they both lack the salivary proteins that bind and inactivate condensed tannins.

Effects of quebracho tannin extract supplementation on methane emissions may also depend upon the amount of condensed tannin provided. If so, the level of condensed tannin supplementation in our study may have been below the threshold required to reduce methane in cattle. Although it is possible that higher amounts of quebracho tannin extract reduce methane, high dietary concentrations of condensed tannins could negatively affect animal performance and may even possibly be toxic (Hervas et al., 2003).

In our study, supplementation with quebracho tannin extract affected protein metabolism by reducing apparent digestibility of CP and ADIN and by lowering ruminal NH_3 concentrations. However, ADG of cattle was not affected, because ME, rather than MP, limited gain (NRC, 1996). Others have reported that condensed tannins reduce absorption of AA reaching the small intestine, reduce CP digestibility, and lower voluntary intakes (McNabb et al., 1996; Priolo et al., 2000). The effects of condensed tannins on protein metabolism could limit animal performance if diets are formulated to meet, rather than exceed, the MP requirements of the cattle. However, for diets containing excess N, the protein-binding effect of condensed tannins could be beneficial for the environment, because reduced N digestion would be expected to reduce the urinary excretion of NH_3, which is highly volatile.

Tannins bind with proteins, forming tannin-protein complexes (Hagerman, 1992), and numerous studies have demonstrated altered protein metabolism in ruminants as a result of this reaction (Aerts et al., 1999). Condensed tannins reduce degradation of plant protein to NH_3 in the rumen, thereby enhancing the flow of feed protein to the intestines. Disassociation of tannin-protein complexes caused by the low pH of the abomasum makes the proteins available for digestion in the small intestine (Waghorn et al., 1987). However, the reduction in apparent digestibility of CP in our study indicates that the tannin-protein complexes were not completely disassociated in the abomasum, thereby lowering the digestion of CP in the total tract. The large decrease in the apparent digestibility of the ADIN fraction also provides evidence that some of the tannin-protein complexes were not completely disassociated, and these complexes may have contributed to fecal ADIN. In our study, ADIN digestibility decreased from 41.6 to 2.8% with increasing levels of quebracho tannin extract. It is well established that the digestibility of ADIN in feeds is variable. Nakamura et al. (1994) reported that approximately 58% of the ADIN in protein supplements was digestible, whereas McBeth et al. (2001) reported that ADIN digestibility ranged from approximately 0 to 42% for heat-treated alfalfa hay.

Supplementing a forage-based diet with up to 1.8% condensed tannins from quebracho tannin extract failed to reduce enteric methane emissions from growing cattle. Although the quebracho tannin extract had no effect on intake or fiber digestibility, the protein-binding effect of condensed tannins was evident. Apparent total tract digestion of CP was reduced by 15% at the highest level of supplementation, indicating that postruminal availability of AA may have been reduced. It is possible that higher levels of quebracho tannin extract supplementation would suppress methane emissions, but potential effects on protein metabolism would have to be considered. Thus, quebracho tannin extract, supplemented up to 2% of dietary DM, is not an effective methane abatement strategy for beef cattle.

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