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Influence of ruminal Quebracho tannin extract infusion on apparent nutrient digestibility, nitrogen balance, and urinary purine derivatives excretion in heifers

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ABSTRACT

Six fully grown heifers (491 kg body weight, standard deviation 35) fitted with ruminal cannulae received incremental dosages of a commercial Quebracho tannin extract (QTE) to investigate its effects on apparent total tract nutrient digestibilities, nitrogen balance, and purine derivatives excretion as an indicator of duodenal microbial crude protein flow. The basal diet comprised 2.6 kg/d grass hay, 2.6 kg/d concentrate feed, and 60 g/d of a mineral premix (as-fed basis) and was offered in two equal meals. The QTE was administered at 0 (CON 1), 1, 2, 4, or 6% of the daily DM intake from the basal diet (i.e., 45 g, 90 g, 180 g, and 270 g/d; as-fed basis). For this, half of the daily QTE dosage was suspended in water and intraruminally infused during each feeding. All animals simultaneously received the same QTE dosage. Every period comprised 9 d of adaptation and 6 d of total urine and feces collection. Subsequent to highest QTE dosage, infusion was ceased and after 14 d of adaptation, urine and feces were collected again for 10 d (CON 2). The QTE infusions at $\geq$4% lowered apparent total tract organic matter digestibility ($P \leq 0.045$). The effects were more pronounced for neutral detergent and acid detergent fiber digestibilities which decreased from 0.718 and 0.626 without QTE to 0.590 and 0.493 at 6% QTE, respectively ($P < 0.001$). Nitrogen excretion linearly decreased in urine ($P = 0.003$) and linearly increased in feces ($P < 0.001$) with incremental QTE dosages. Irrespective of the dosage level, nitrogen retention was higher with than without QTE infusion ($P \leq 0.035$). Urinary purine derivatives excretion declined from 103 mmol/d at 1% QTE to 80 mmol/d at 6% QTE ($P < 0.001$), indicating a 36% decrease in estimated duodenal microbial crude protein flow. At QTE dosages of $\geq$4% of DM intake, reduced carbohydrate digestibility will lower energy supply to the host animal. The pronounced decrease in estimated microbial protein synthesis even at moderate QTE levels is unlikely to be compensated by the increase in rumen-escape protein. The QTE addition to ruminant diets might not improve protein supply and performance of cattle.

1. Introduction

Protein is one of the most expensive dietary components in ruminant nutrition. Low to moderate concentrations (2–4%) of condensed tannins in ruminant diets are considered to increase post-ruminal flow of non-ammonia nitrogen (N) due to their ability to form reversible complexes with feed proteins and thereby protect them from rumen

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degradation and enhance animals' protein supply (Jones and Mangan, 1977; Barry and Manley, 1984; Min et al., 2003). Hence, there is much interest in the strategic use of condensed tannins in commercial ruminant feeding to enhance protein use efficiency. However, although condensed tannins primarily form complexes with proteins, they may also bind to minerals and polysaccharides such as starch, cellulose, hemicellulose, and pectin, thereby retarding their fermentation (Jansman, 1993; Bravo, 1998; Smith et al., 2005). Moreover, they may inhibit rumen microbial growth depending on the type of tannin, its source and dietary concentration, and the composition of the rumen microbial consortium (McSweeney et al., 2001; Smith et al., 2005). Slightly reducing the rate of protein degradation may increase efficiency of microbial crude protein (MCP) synthesis due to a synchronization of nutrient release (Makkar, 2003) as well as the inhibition of certain microbial species that are mainly responsible for protein degradation (Jones et al., 1994; Min et al., 2002; Vasta et al., 2010).

Quebracho tannin extract (QTE) is extracted from the heartwood of Quebracho tree (*Schinopsis lorentzii* (Engl.) and *Schinopsis balansae* (Engl.) found in the forests in the *Chaco* region of Argentina, Bolivia, and Paraguay. The QTE has frequently been used as a condensed tannin source in animal studies investigating its ability for e.g. improving body weight gain (Min et al., 2006), milk production (Dschaak et al., 2011), or efficiency of N utilization (Mezzomo et al., 2011) as well as reducing methane emissions (Beauchemin et al., 2007). Only a few studies investigated effects of QTE covering a broad range of dietary concentrations to examine its dose-dependency.

The present study aimed at analyzing the influence of low to high concentrations of QTE in the diet on rumen carbohydrate digestibility, N turnover and partitioning, and urinary purine derivatives (PD) excretion as an indicator of duodenal MCP flow. We hypothesized that QTE effects are dose-dependent and that even low QTE dosages will decrease ruminal protein degradation without affecting MCP synthesis and carbohydrate fermentation. It is expected, that moderate to high QTE dosages will reduce organic matter and especially protein and structural carbohydrate fermentation, thus limiting rumen microbial growth and reducing overall MCP supply to the host animal.

2. Material and methods

2.1. Animals, feeding, and experimental design

Six adult heifers fitted with ruminal cannulae were used (Jersey × German Black Pied Lowland). The animals were non-lactating, non-pregnant and housed in individual tie stalls with free access to fresh drinking water. The animals were offered a basal diet (as-fed basis; Table 1) of 2.6 kg/d of hay, 2.6 kg/d of concentrate feed, and 60 g/d of a mineral premix that met their energy requirements for maintenance and utilizable crude protein (uCP) according to the GfE (2001). The composition of the concentrate feedstuff was as follows (on fresh matter basis): barley grain (35%), wheat grain (35%), sugar beet pulp (15%), and rapeseed meal (15%). Prior to the study, the grass hay was chopped (10–15 cm length), mixed well, and stored until

Table 1
Chemical composition of the grass hay and the concentrate feed (arithmetic means ± standard deviations; n=6 samples).

		Hay	Concentrate
DM	% FM	86.1 ± 1.1	87.3 ± 0.5
OM	% DM	94.4 ± 0.6	96.0 ± 0.0
CP		10.0 ± 0.4	16.5 ± 0.2
CL		1.2 ± 0.2	2.3 ± 0.1
NDF		77.6 ± 3.9	27.8 ± 3.5
ADF		38.0 ± 0.8	10.8 ± 0.6
ADL		3.0 ± 0.2	1.7 ± 0.2
Starch		n.d.	41.4 ± 0.6
ME	MJ/kg DM	9.2 ± 0.2	11.7 ± 0.1
IvdOM	%	65.4 ± 0.9	78.5 ± 0.8

FM—fresh matter; DM—dry matter; OM—organic matter; CP—crude protein; CL—crude lipid; NDF—neutral detergent fiber (inclusive residual ash); ADF—acid detergent fiber (inclusive residual ash); ADL—acid detergent lignin; ME—metabolizable energy; IvdOM—in vitro-digestibility of organic matter; n.d.—not determined.

feeding. At the same time, concentrations of dry matter (DM) were measured in grass hay and concentrate to calculate DM intakes of the experimental animals and hence, to determine the required QTE dosages. The basal diet was offered in two equal meals at 7:30 AM and 5:30 PM. The QTE product was a spray-dried moistened powder (Indusol ATO) produced in Argentina (Silvateam S.p.a., San Michele M.vì, Italy) containing 68.6% total tannins and 15.9% condensed tannins (on fresh matter basis; determined with butanol–HCL method after Terrill et al. (1992).

The study consisted of six periods, starting with a control period without QTE infusion (CON 1), followed by four consecutive periods in which all animals simultaneously received the same amount of QTE. Daily QTE dosages were 1, 2, 4, and 6% of animals' DM intake (i.e. 45 g, 90 g, 180 g, and 270 g/d; as-fed basis). At each feeding, half of the daily QTE dosage was suspended in 1 l of lukewarm water and administered via the rumen cannula. Each period comprised 9 d of treatment adaptation followed by 6 d of total urine and feces collection. Subsequent to the 6% QTE dosage, a second control period (CON 2) was conducted and urine and feces were collected again for 10 d, after 14 d of adaptation to the basal diet to minimize any carry-over effects.

This experimental design does not allow for exclusion of possible cumulative or residual effects of the previous QTE dosage. However, any effects of the period (i.e. advancing time of experiment) are unlikely, since (i) all meals had been prepared before the experiment started and their chemical composition did not differ between periods; (ii) non-growing and non-pregnant heifers were used and fed at maintenance energy and protein level with a constant DM intake across all periods; and (iii) animal and feeding management and climatic conditions were very similar during all periods. Furthermore, due to the high turnover rates of the microbial consortium, it is expected that the microbial ecosystem and with it protein and carbohydrate degradation pattern reached a steady state to the new tannin dosages after 9 d irrespective of the previous treatment.

Individual water intakes were measured by water meters attached to the animals' drinking troughs. The