Influence of dietary tannin levels on methane production from ruminant livestock: A meta-analysis

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Introduction

Tannins represent a class of plant secondary metabolites and are produced by plants in their intermediate metabolism. Tannins are considered to be a promising group of substances to decrease methane (CH_4) emission from ruminants by dietary means. However, there is no common agreement whether tannins generally decrease CH_4 formation *in vivo* or not and to which extent (Beauchemin *et al.*, 2008). Therefore, synthesis of research on this particular topic is needed, to summarize and to quantify the tannin effects on CH_4 production from ruminants and its associated variables. The objective of this study was to estimate the relationship between tannin levels and CH_4 emission from ruminant animals by compiling available literature data of respective experiments using a statistical meta-analysis approach.

Material and methods

A database was created from *in vivo* experiments testing tannins as dietary supplements (both condensed and hydrolysable tannins) and giving CH_4 production as a measured variable. The database contained experimental factors (animal type, body weight, tannin source, tannin level) and various observed variables (digestibility, ruminal ammonia concentration, body nitrogen (N) retention, CH_4, volatile fatty acids (VFA) and protozoal counts). Results from a total of nine publications reporting results from *in vivo* experiments with both small (goat, sheep) and large ruminants (cattle) were used. In total 25 dietary tannin treatments were pooled in the database (Sliwinski *et al.*, 2002; Carulla *et al.*, 2005; Puchala *et al.*, 2005; Oliveira *et al.*, 2007; Beauchemin *et al.*, 2007; Tiemann *et al.*, 2008; Animut *et al.*, 2008a; Animut *et al.*, 2008b; Grainger *et al.*, 2009). The variables being dependent on body size (N retention and CH_4 production) were standardized by relating them to metabolic body weight ($BW^{0.75}$) to counterbalance the variation associated with body weight among and within ruminant species.

The analysis of the data assembled in the database was made by a statistical meta-analysis approach (St-Pierre, 2001; Sauvant *et al.*, 2008). Experiments were treated as random effects whereas tannin levels were treated as fixed effects using the following model:

$$Y_{ijk} = \mu + Tannin_i + Exp_j + E_{ijk},$$

where Y_{ijk} = observations, μ = overall mean, $Tannin_i$ = fixed effect of tannin levels (in g/kg feed dry matter), Exp_j = random effect of experiments, and E_{ijk} = random residual error. The model was applied without weighting the observations for standard errors and the procedure MIXED of SAS version 9.1 was used.

Results and conclusion

The evaluation showed that increasing dietary tannin levels linearly decreased ($P=0.008$; $R^2=0.73$) daily CH_4 emission per kg $BW^{0.75}$ (Table 1). This was accompanied by linear decreases of log protozoal counts ($P=0.003$; $R^2=0.93$) and of organic matter digestibility

($P<0.001$; $R^2=0.94$). Tannin level did not significantly affect N retention and VFA profiles. Still a linear decrease was also observed for CH_4 production per unit of organic matter digested with increasing tannin levels ($P<0.001$; $R^2=0.93$). These findings suggest that increasing dietary tannin levels appears to decrease CH_4 production from ruminants. However, the effect is accompanied by a reduction in organic matter digestibility though at a lower magnitude than CH_4 abatement. Methane mitigation seems to be associated with a decrease in protozoal growth where part of the methanogens is attached.

Table 1. Meta-analysis of tannin levels (X; in g/kg feed dry matter) and dependent variables (Y).

					P-value		
Variable	n exp	n treat	Intercept	Slope	Intercept	Slope	R^2
Organic matter digestibility (%)	6	17	66.7	–0.122	<0.001	<0.001	0.94
Ruminal ammonia (mmol/l)	9	22	9.44	–0.020	<0.001	0.012	0.64
Body N retention (mg/kg $BW^{0.75}$ per day)	5	15	145.6	0.798	ns	ns	0.33
CH_4 (l/kg $BW^{0.75}$ per day)	9	25	1.97	–0.005	<0.001	0.008	0.73
CH_4/OM digested (l/kg)	6	17	2.9	–0.148	<0.001	<0.001	0.93
Total VFA (mmol/l)	7	18	93.8	–0.089	<0.001	ns	0.24
C_2 (% of total)	7	18	69.8	–0.004	<0.001	ns	0.05
C_3 (% of total)	7	18	18.2	0.0004	<0.001	ns	0.00
C_2:C_3	7	18	4.24	0.0005	<0.001	ns	0.00
log protozoal counts (10^5/ml)	4	11	6.07	–0.003	<0.001	0.003	0.93

n exp, number of experiments; n treat, number of treatments; BW, body weight; C_2, acetate; C_3, propionate

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