Can Plant Saponins Lower Methane Emissions Without Hampering The Nutrient Digestibility of Ruminants?

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ABSTRACT

Plant saponins have been used as additives to mitigate methane emissions originated from enteric fermentation of ruminant animals. Most of the studies however were based on *in vitro* techniques, and only limited studies were directly conducted on the animals. Inconsistencies of saponin effects on methane emissions have been previously observed, which might be related to their levels in rations. The present study was aimed to assess the effects of saponin levels on methane emissions and nutrient digestibility of ruminants *in vivo* by integrating data from multiple studies. A number of studies across 11 published articles were integrated into a database. Both small and large ruminant species were included. Searching of the articles was performed by using Scopus with keywords "saponin" and "methane". The main criteria for a paper to be included were: (1) studies were conducted *in vivo*, (2) saponin contents were reported, and (3) methane was directly measured, not estimated by any methods. Parameters included in the database were methane emissions and nutrient digestibility. Data were analyzed by the statistical meta-analysis approach based on mixed model methodology. Different studies were treated as random effects while saponin levels in diets, i.e. control (no saponins), low ($0 <$ saponins ≤ 5 g/kg) and high (saponins > 5 g/kg), were considered as fixed effects. Results revealed that, across all studies, methane emissions decreased significantly when saponins were added at both low and high levels ($P<0.05$), suggesting that the use of saponins for ruminants is beneficial in term of environmental conservation. Low levels of saponins increased nutrient digestibility as compared to control ($P<0.05$) while, on the contrary, high levels decreased the nutrient digestibility ($P<0.05$). It can be therefore concluded that the use of saponins at low levels is able to lower methane emissions of ruminants without hampering their digestibility.

Keywords: saponin, methane, ruminant, production, meta-analysis

INTRODUCTION

Ruminants are among the contributors of methane accumulation in the atmosphere and contribute to global warming (Moss et al., 2000). Such methane emission is also a form of energy loss from the animals which may account up to 14% loss from digestible energy intake (Cottle et al., 2011). Plant saponins have been used as additives to mitigate methane emissions originated from enteric fermentation of ruminant animals. Most of the studies however were based on *in vitro* techniques, and only limited studies were directly conducted on the animals. Inconsistencies of saponin effects on methane emissions have been previously observed (Lila et al., 2005; Li and Powers, 2012), which might be related to their levels in rations. Furthermore, nutrient digestibility was varied by addition of plant saponins. The present study was therefore aimed to assess the effects of saponin levels on methane emissions and nutrient digestibility of ruminants *in vivo* by integrating data from multiple studies.

MATERIALS AND METHODS

Database development: Reports on the use of saponins to mitigate *in vivo* methane emissions of ruminants were integrated in a database; both small and large ruminant species were included. Searching of literatures was performed by using the Scopus database with keywords “saponin” and “methane”. The main criteria for a paper to be included were: (1) studies were conducted *in vivo*, (2) saponin contents were reported, and (3) methane was directly measured, not estimated by any methods. Data originated from *in vitro* rumen fermentation experiments were excluded and reported elsewhere (Jayanegara et al., 2014). Accordingly, a total of 11 articles comprised of 17 studies were obtained and used to construct the database. Apart from information on saponin sources, application levels and methane emissions, nutrient digestibility was also recorded, i.e. dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) digestibility. After collection, different units of measurements within a particular parameter were transformed into similar units in order to allow direct analysis. Various plant sources of saponins were tabulated, i.e. sapindus, yucca, quillaja, alfalfa and tea. Saponin levels (ranged from 0 to 40 g/kg) were classified into three groups, namely control (no saponins), low ($0 < \text{saponins} \leq 5$ g/kg) and high ($\text{saponins} > 5$ g/kg) levels. Justification of 5 g/kg of saponins to separate the low and the high saponin groups was based on the average saponin levels across all studies included in the database.

Statistical analysis: The data obtained were subjected to a statistical meta-analysis based on mixed model methodology (Sauvant et al., 2008). Accordingly, different studies were treated as random effects whereas categorical levels of saponin additions were considered as fixed effects. The following statistical model was used:

$$Y_{ij} = \mu + s_i + \tau_j + s\tau_{ij} + e_{ij}$$

where Y_{ij} = dependent variable, μ = overall mean, s_i = random effect of the *i*th study, τ_j = fixed effect of the *j*th level of factor τ, $s\tau_{ij}$ = random interaction between the *i*th study and the *j*th level of factor τ, and e_{ij} = the unexplained residual error. No weighting procedure was applied for different studies. When a variable showed significant difference at $P<0.05$ between various saponin levels, Duncan’s multiple range test was employed to compare the difference between means. All statistical analyses were performed with IBM SPSS Statistics version 20.

RESULTS AND DISCUSSION

Across all studies, methane emissions decreased significantly when saponins were added at both low and high levels ($P<0.05$) (Figure 1), suggesting that the use of saponins for ruminants is beneficial in term of environmental conservation. The decrease of methane emissions due to saponin additions at low and high levels was 8.6% and 7.3% lower than that of control, respectively. There was no statistical difference between administration of low and high levels of saponins on enteric methane emissions. Saponins lower methane emissions through a direct inhibition on methanogen population in the rumen (Narvaez et al., 2013) and an adverse effect on the activity of methanogen (Guo et al., 2008). Saponins also reduce a certain population of protozoa where part of the methanogens is living symbiotically with the fauna. Further, protozoa provide hydrogen as a substrate for methanogenesis (Morgavi et al., 2010). Therefore, such decrease of protozoa population may lead to a decrease in methanogen population as well as methane emissions.

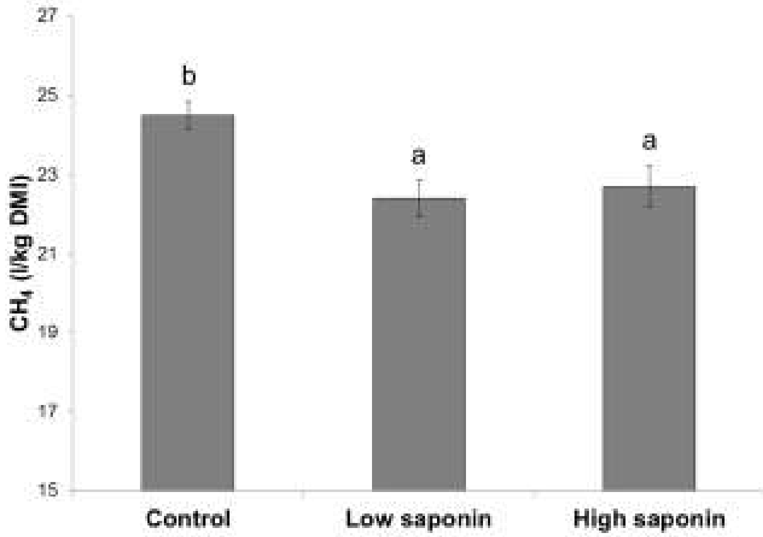

Figure 1. Influence of saponin additions at low (0 < saponins ≤ 5 g/kg) and high (saponins > 5 g/kg) levels on methane emissions (l/kg dry matter intake) from ruminants.
Different letters above the bars show significantly different at P<0.05.

Low levels of saponins increased nutrient digestibility as compared to control (P<0.05) while, on the contrary, high levels decreased the nutrient digestibility (P<0.05). Such pattern was true DMD, OMD, NDFD and ADFD (Table 1). In the case of CPD, addition of saponins at low levels did not significantly improved the digestibility parameter but it was significantly higher than that of high saponin additions (P<0.05). Apparently, saponins at low levels (e.g. less than 5 g/kg) are favorable in simultaneously mitigating enteric methane emissions and stimulating nutrient digestibility. When being added at high levels, saponins seem to cause an adverse effect on nutrient digestibility without any further reduction in methane emissions. Therefore, since there is no advantage of adding saponins at high levels, the addition is sufficient at low levels.

Table 1. Digestibility of nutrients on saponin additions at low (0 < saponins ≤ 5 g/kg) and high (saponins > 5 g/kg) levels.

Parameter	N	Control	Low saponin	High saponin	SEM
DMD (g/kg)	13	647^{b}	663^{c}	603^{a}	13.7
OMD (g/kg)	20	650^{b}	701^{c}	611^{a}	17.2
CPD (g/kg)	26	629^{ab}	645^{b}	620^{a}	15.1
NDFD (g/kg)	26	545^{b}	583^{c}	509^{a}	19.5
ADFD (g/kg)	21	486^{b}	537^{c}	454^{a}	28.4

DMD, dry matter digestibility; OMD, organic matter digestibility; CPD, crude protein digestibility; NDFD, neutral detergent fiber digestibility; ADFD, acid detergent fiber digestibility; N, number of data; SEM, standard error of the mean.
Different superscripts within the same row show significantly different at P<0.05.

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