Review Article

Alternative Strategies of Plant Metabolite Secondary "Tannin" for Methane Emissions Reduction on Ruminant Livestock a Reviews of the Last 5 Years Literature

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Abstract | An increasing global population will link the increasing livestock sector contribution to meet food security. Recently, livestock production has encountered great challenges related to excessive methane emissions that have a negative impact on the environment. It requires special attention to the loss of feed energy from the methane gas formation process. Public fretfulness agreed that the gas produced by ruminants is a big factor in the effects of global warming. Alternative the decrease in methane production from ruminants is by utilizing secondary metabolite compounds in plants. These studies are interesting to be continued and explored in an effort to reduce methane production through *in vitro* and *in vivo*, because it is proven that there are many types of biological or agro-industrial waste in the world different contents, structures and benefits. This review of the last 5 years related to the utilization of tannin active compounds showed the effect on the reduction of methane production. Condensed tannin (CT) and hydrolyzed tannin (HT) types both play an important role in reducing methane, but CT is widely studied because of its presence which is more commonly found. The concept of tannin utilization still presents its own challenges to focus on the dose of administration, the structure of the tannin itself, the substitution of other ingredients and also includes the types of animals given treatment.

Keywords | Environment, Methane, Ruminant, Tannin, Global warming

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INTRODUCTION

Livestock production is one of the major contributors to greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2). These gases contribute greatly to global warming, environmental degradation and pollution. Livestock production system is responsible for 18% CH_4 and 9% CO_2 productions of all greenhouse gases emissions. Methane has a greater global warming effect (about 23 times) more than CO_2 (Ugbogu et al., 2019). Lakhani and Lakhani (2018) stated that methane makes up 16% of total global GHG emissions which is probably the second most important gas after CO_2 contributing to global warming. Methane has 23 times more global warming potential than carbon dioxide. Naumann et al. (2015) added that stated that ethane emissions from ruminant livestock contribute to total anthropogenic greenhouse gas emissions and reduce metabolizable energy intake by the animal.

In ruminants, approximately 95.5% of CH_4 generation is produced by fermentation of feed in the rumen (Lakhani and Lakhani, 2018). Dairy cows are responsible for significant emissions of centrifuge of methane (CH_4) and produce nitrous oxide (N_2O) and ammonia (NH_3) gas from manure (Duval et al., 2016). Livestock production encounters a great challenge of increasing production to meet global demand for agricultural products and at the same time reduces environmental impact. Many researchers have reported the effects of substituting phytoconstituents such as tannins and saponins as chemical feed additives to modify rumen fermentation (Ugbogu et al., 2019).

Ku-vera et al. (2020) stated that plant secondary metabolites are shown to rationally modulate the rumen microbiome and modify its function, reduce feed energy loss as methane in ruminants, rumen microbial species increase protein and degradation of fiber in a tropical feed plant species. Dermitas et al. (2018) stated that effects of plant secondary metabolites on ruminal fermentation are favorable if they increase or do not change VFA production (or with a desirable change in molar proportions of VFA) and feed digestibility while they decrease ammonia concentration and methane production. Ugbogu et al. (2019) added that natural plant products (NPP) or secondary metabolites have the potential to improve rumen fermentation, reduce loss of feed energy, improve animal health and productivity, increase animal lifetime performance, and reduce greenhouse gases production-CH_4 and CO_2 during animals' production. Rira et al. (2019) emphasized that secondary plant metabolites can be used as feed additives to reduce CH_4 production and to consequently mitigate greenhouse-gases emission. This study will focus on providing information on the last 5 years related to the role of active tannin plant compounds as an alternative to reduce ruminant livestock methane gas production. It is hoped that the results of this study can be used as a reference in conducting research to emphasize the upcoming methane gas production.

Alternative treatment to reduce methan production

Methane (CH_4) emissions caused by ruminants arise from fermentation of feed in the rumen. Methane is an important cause of the greenhouse effect and at the same time causes energy loss from livestock so that it can cause a decrease in productivity. Because methane emissions are affected by feed, ruminant nutritionists are invited to focus their studies on feed strategies that can reduce methane production (Adegbeye et al., 2019). Plant resources such as legumes or agro-industrial wastes contain condensed tannins consisting of flavon-3-ol polymer units that have the potential to suppress methane production (Mueller-Harvey et al., 2019). Some studies have shown that the use of condensed tannins generated diets has decreased methane emissions (Piñeiro-Vázquez et al., 2018).

Hoehn et al. (2018) emphasized that one of the well-known types of plant secondary metabolite compounds helps the production of livestock, condensed tannins, which are polyphenol compounds having the ability to modulate rumen fermentation, suppress the production of methane. Adejoro et al. (2019) asserted that tannins have been shown to be important phytochemicals in ruminant production due to various biological activities and reduced emissions of enteric methane in ruminant animals. Zeller et al. (2019) added that the positive impact of the potential active plant compounds in the form of tannins on plants could reduce methane emissions.

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Tannins effect on reduction of methan production

Recent developments regarding the evaluation of the content of secondary metabolites (tannins) in plants and/ or agricultural industrial waste in an innovative effort to suppress methane production in ruminants in the last 5 years are shown in **Table 1**. The use of plant secondary metabolites as a natural alternative to reduce the impact of livestock on the environment continues to attract great interest globally (Chen et al., 2015). Natural strategies to reduce methane production are utilizing tannin sources in plants. Tannins are classified into hydrolyzed tannins (HT) and condensed tannins (CT). The reduction in CH_4 yield (g CH_4 per kg DMI) with tannin utilization has been ascribed to direct negative impacts on microbial populations (Pineiro-Vazquez et al., 2015). But, Sliwiński et al. (2002) reported that tannins did not show any effect on methanogenesis or even CH_4 enhanced production in sheep. These differences could be the result of dosage, type and source of tannins or the type of feed. Patra et al. (2011) stated that molecular weight is a key factor for its effect on digestive enzymes and microbes in the rumen. Low molecular weight tannins could be more effective inhibitors of microbes, including methanogens, compared with high molecular weight tannins.

Table 1: Tannin effect for CH4 reduction in rumen.

No.	Kind of plant	Test system	Doses	Effect on CH4	Reference
1	*L. leucocephala*	*In vitro*	Supplemented with 30.0% on feed basis	Decrease ,25.8 L kg−1	Albores-Moreno *et al.*, 2019
	P. piscipula			Decrease, 29.5 L kg−1	
	N. emargiata			Decrease, 30.6 L kg−1	
	T. amygdalifolia			Decrease, 31.8 L kg−1	
2	*B. variegata*	*In vitro*	Supplemented 1%	Decrease, 34.82 mmoles	Deuri *et al.*, 2019
3.	*P. granatum* *T. undulata*	*In vivo*	2% of dry matter intake	Decrease, 46% Decrease, 42%	Hundal *et al.*, 2019
4	*A. julibrissin*	*In vitro*	500 mg	2.55 w/0 PEG	Bouazza *et al.*, 2019
	A. nilotica			1.72 w/0 PEG	
	P. granatum			2.63 w/0 PEG	
	V. faba *A. herba-alba*			4.92 w/0 PEG 1.63 w/0 PEG	
	A. halimus			0.93 w/0 PEG	
	C. azel			0.13 w/0 PEG	
5.	*A. mearnsii*	*In vitro*	5% DM	reduced by 7% to 9%	Sinz *et al.*, 2019
	V. vinifera			reduced by 7% to 9%	
	C. sinensis			reduced by 7% to 9%	
6	Condensed tannins	*In vivo*	0	2.99 % of GE intake	Ebert *et al.*, 2017
	(By-Pro; Silvateam		0, 0.5	Increase 3.12% of GE intake	
	USA, Ontario, CA)		1	Increase 3.09% of GE intake	
7.	*F. benghalensis* *A. heterophyllus*	*In vivo*	10 parts w/w on concentrate	Decrease, 19.5 CH4 (g/d) Decrease, 19.4 CH4 (g/d)	Malik *et al.*, 2017
	A. indica			Decrease, 18.1 CH4 (g/d)	
8.	*A. mearnsii*	*In vivo*	120 g extract	Decreased 32%	Alves *et al.*, 2017
9.	*G. biloba*	*In vitro*	1.6% extract	Decreased 53%	Oh *et al.*, 2017
10.	*C. papaya*	*In vitro*	5 mg/0.25g DM	Decrease 13%	Jafari *et al.*, 2017
			10 mg/0.25g DM	Decrease 16%	
			15 mg/0.25g DM	Decrease 34%	
11.	*C. sinensis*	*In vitro*	0.8%	Decrease 48.55 ml/gm	Jadhav *et al.*, 2016
12.	Quebracho and chestnut trees	*In vivo*	0.45% tannin	56 cow−1 day−1	Duval *et al.*, 2016
			1.8% tannin	48 cow−1 day−1	
13.	Mimosa	*In vitro*	38 mg	23%	Jayanegara *et al.*, 2015
	Quebraco			27%	
	Chesnut			23%	
	Sumac			20%	
14.	*A. taxiformis*	*In vitro*	2% of the control OM (w/w)	12.32 mL g−1 OM	Vucko *et al.*, 2017
15.	*O. viciifolia*	*In vitro*	40 g/kg of DM	19.4 %	Hatew *et al.*, 2016
	(Cotswold Common)		80 g/kg of DM	16.1 %	
			120 g/kg of DM	12.9 %	
16.	*D. paniculatum*	*In vitro*	45%	Decrease 65.6%	Nauman *et al.*, 2015
	S. lespedeza		45%	Decrease 24.2%	
17.	*Porphyra sp*	*In vivo*	10% of DM	Not influenced CH4	Lind *et al.*, 2020
18.	*C. avellana*	*In vitro*	30.4% basal diet	1.31 mmol/g DM	Niderkorn *et al.*, 2020
	O. viciifolia		8.2% basal diet	1.34 mmol/g DM	

No.	Kind of plant	Test system	Doses	Effect on CH4	Reference
19.	Banana pseudo stems	*In vitro*	25.6 g squeezed and 26.5 g unsqueezed	12.5%	Pan *et al*., 2020
20.	*L. leucocephala*	*In vitro*	2 mg/100 mg DM	12.5	Petlum *et al*., 2019
			6 mg/100 mg DM	5.8	
	A. indica		2 mg/100 mg DM	3.3	
			4 mg/100 mg DM	1.7	
21.	*A. mearnssii*	*In vivo*	30 g Acacia/kg of dietary DM	Decrease, 0.16 g/kg DM	Denninger *et al*., 2020
22.	*M. tenuiflora*	*In vivo*	30 g/kg DM	Decrease, 35.9 L/day	Lima *et al*., 2019
23.	*M. stenopetala*	*In vitro*	extract 200 mg	51.66 ml g-1 DM	Tirfessa and Adugna, 2019
	A. nilotica		extract 200 mg	18.33 ml g-1 DM	
24.	*O. vocoofolia*	*In vitro*	500 mg	3.7 mL/mmol	Rufino-Moya *et al*., 2019
	H. coronarium		500 mg	3.4 mL/mmol	
25.	*A. mearnssii*	*In vivo*	50 g/kg feed	Decrease, 19%	Adejoro *et al*., 2019
26.	*S. cumini*	*In vivo*	50% basal diet	Reduction, 18.9%	Baruah *et al*., 2019
	M. bombycina		50% basal diet	Reduction, 20.9%	
27.	Chestnut and quebra-cho mix	*In vivo*	1.5%	Decrease, 20.6 g/kg DMI	Aboagye *et al*., 2018
28.	*G. march*	*In vivo*	34.9 mg CT	Decrease, 33.03 mL/g DM	Hixson *et al*., 2018
29.	*D. paniculatum*	*In vitro*	508 nm	4.9 g/kg DM	Naumann *et al*., 2018
	L. stuevei		543 nm	4.9 g/kg DM	
	L. cuneata		543 nm	15.1 g/kg DM	
	M. strigillosa		547 nm	7.6 g/kg DM	
	D. illinoensis		547 nm	24.9 g/kg DM	
	N. lutea		547 nm	19.7 g/kg DM	
	L. retusa		547 nm	40.7 g/kg DM	
	A. angutissima		547 nm	0.6 g/kg DM	
	A. angustissima STX		538 nm	0.8 g/kg DM	
30.	*Lespedeza*	*In vivo*	1.46 kg/d DM	1.36 Mj/d	Liu *et al*., 2018
			1.23 kg/d DM	0.76 Mj/d	
			1.30 kg/d DM	0.84 Mj/d	
			1.18 kg/d DM	0.71 Mj/d	
			1.32 kg/d DM	0.71 Mj/d	
			1.10 kg/d DM	0.66 Mj/d	
			1.02 kg/d DM	0.65 Mj/d	
			1.20 kg/d DM	0.68 Mj/d	
			1.01 kg/d DM	0.68 Mj/d	

Hydrolyzed and condensed tannins appear to have a role in limiting methane production, but the research currently has focused largely on CT because of their wide distribution among forages. Most studies are limited to dose-response information, and there is almost no information about the structure of tannins or chemical properties (Mueller-Harvey, 2006). Condensed tannin is a diverse class of compounds, in which efforts to suppress the production of methanogen depend on the dose of administration and focus more on the structure of CT, the composition and ability of CT extraction to put more emphasis on methanogenic (Huyen et al., 2016). However, Carrasco et al. (2017) have another opinion, where the decrease in methane production caused by methanogenic bacterial using addition of a mixture of HT and CT, compared with HT itself or CT itself. Meanwhile, Rira et al. (2019) found that HT and CT similarly showed inhibition of CH_4 production, but HT was not followed by adverse effects of digestive rumen fermentation while CT showed an adverse effect on rumen fermentation. In addition, Hatew et al.

(2016) also stated that CT forming or structural features need to get focus, including the size of the polymers and the structural characteristics of flavanols. Nauman et al. (2015) added that the structural components of CT are not commonly determined, not many of them have discovered the properties of CT that play a good role in suppressing methane production.

The role of active plant compounds (tannins) in feed nutrition varies and is influenced by several factors such as tannin concentrations in feed, biological characteristics of tannin compounds, animal species, prolonged and adaptation effects of feed (Archimède et al., 2016). Animut et al. (2008) explained that tannin was also associated with inhibition of the growth of the methane-producing community through the tannin action of their functional proteins, resulting in bacteriostatic and bactericidal effects or indirectly there is defaunating in methanogen-related protozoan populations. Naumann et al. (2015) related to the correlation of antioxidants on methane production. CT galloylation has a correlation increasing the antioxidant activity of flavan-3-ols. A strong nonlinear correlation was observed between antioxidant activity (TE per g of plant tissue) and methane production (g CH_4 per g of plant tissue).

The effectiveness of active plant compounds in the mission of reducing methane production is also influenced by animal species. Roque et al. (2019) stated that the utilization of the Asparagopsis genus plant which was included in 1% of the total feed of dairy cows succeeded in reducing 67% of energy CH_4 emissions, while Li et al. (2018) stated that the utilization of plants with the genus was tested on sheep with concentrations of 0.5%, 1%, 2 % and 3% succeeded in reducing enteric CH_4 to 80% compared to control cattle. Addition of tannin to the feed does not always have an impact on reducing methane production. Lima et al. (2019) stated that in vivo treatment in sheep by adding tannin 30g/kg DM did not influence the decreasing of methane production L/day (P = 0.14). Lind et al. (2020) emphasized that the addition of *clover silage* (CLO), *soybean meal* (SOY) or *Porphyra* sp. (POR) does not contribute to the decrease in methane production through *in vitro* and *in vivo* in sheep.

The availability of tannins in plants can be used as an alternative to reduce methane production, in a way suppress H_2 availability, and reduce fiber digestion (Vucko et al., 2017), and/or maximizing the content of active plant compounds in the form of condensed tannins to influence methanogenic archaea populations and their activities in the rumen (Saminathan et al., 2016). Bouazza et al. (2019) found that legume plant species in Algeria *Albizia julibrissin* (pods), *Acacia nilotica* (pods), *Punica granatum* (leaves and pericarp), *Vicia faba* (leaves), *Artemisia herba-alba* (aerial part), *Attriplexhalimus* (leaves) and *Calligonum azel* (bark) have been proven to have reduced methane to 0.13 w/o PEG. Niderkorn et al. (2020) stated that condensed tannins in *C. avellena* with a concentration of 30.4% from the basal diet decreased the production of methane 1.31 mmol/g DM DM. Denninger et al. (2020) also found that the addition of *Acacia mearnssii* bark at a concentration of 30 g Acacia/kg of DM in vitro decreased methane production of 0.16 g/kg DM. Albores-moreno et al. (2019) explained that supplementation with *L. leucocephala, P. piscipula, N. emargiata* and *T. amygdalifolia* in ruminant diets was based on decreased production of enteric methane by 15.6 to 31.6%. Sinz et al. (2019) stated that tannins on acacia, grape seed and green tea plants provide reduced methane formation 7% to 9% through *in vitro*.

CONCLUSIONS AND RECOMMENDATIONS

The conclusion from the last 5 years review results that tannins remain proven to emphasize methane production through in vitro and in vivo, both CT and HT. The use of HT did not have an effect on rumen digestion fermentation, but until the latest development of CT, it has been associated with many treatments for decreased methane production. The success of suppressing methane production with the use of active tannin compounds is influenced by the number of doses and types of tannins, the content of tannins in plants, and the types of animals whose methane production will be suppressed.

NOVELTY STATEMENT

This review addresses the role of tannins in the plants as an alternative natural strategy to reduce methane emission production in ruminants reported in the last 5 years literature.

AUTHOR'S CONTRIBUTION

ZAB and AAA wrote the manuscript. IW and BS edited the final version of the manuscript. All authors contributed to manuscript revision, intellectual content, and approved the manuscript for publication.

Conflict of interest

The authors have declared no conflict of interest.

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