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Summary

Our objective was to determine how replacing forage with dried distillers grains plus solubles (DDGS) affects ruminal methane production. Methane produced by lambs and ruminal cultures was quantified following the substitution of brome hay with DDGS. In vitro and in vivo methane production is reduced when brome hay is replaced with DDGS. A reduction in methane production in vitro is not associated with a reduction in energy produced in the form of volatile fatty acids or dry matter disappearance. Decreased ruminal methane production would increase the retention of gross feed energy and may explain the increase in ADG realized when DDGS are used to supplement cattle receiving a forage-based diet.

Introduction

Ruminal methane production accounts for a 3 to 12% loss of feed gross energy. This loss is greatest for cattle consuming forage-based diets and decreases with increasing amounts of concentrate included in the diet. Readily fermentable carbohydrates result in less methane produced per unit of digested DM. Methane also is a potent greenhouse gas. Decreasing ruminal methane emissions would decrease the amount of atmospheric methane contributed by agricultural activities and help mitigate global warming.

Supplementation of cattle consuming a forage-based diet with dried distillers grains increases ADG, DMI, and DM digestibility. However, the effect of such supplementation on ruminal methane production has not been investigated. The objectives of this work were to: 1) determine if replacing dietary forage with dried distillers grains plus solubles (DDGS) decreases ruminal methane production and 2) determine if any such effect can be attributed to the corn bran versus the non-fiber (protein + fat) component of the DDGS.

Procedure

In vitro methane production

Ruminal fluid extracted from a fistulated heifer receiving a mixed forage and concentrate diet was used to inoculate cultures (n = 4/treatment) provided with approximately 10 mg DM/mL of substrate that consisted of 100% brome hay (0%), 25% DDGS and 75% brome hay (25%), 50% DDGS and 50% brome hay (50%), 75% DDGS and 25% brome hay (75%), or 100% DDGS (100%). Nutrient content of the substrates is outlined in Table 1. In addition to the substrate and ruminal fluid inoculum cultures contained a modified McDougall's buffer, distilled H_2O, trypticase, resazurin, a micro mineral solution, and Na_2S. Following the addition of media to 40 mL glass vials, an oxygen-free environment was created by purging each of the cultures with CO_2. The vials were then sealed, pressurized to 100 kPa above atmospheric pressure, and allowed to incubate in a shaker (102°F) for 22 hours. Following incubation, headspace pressure was measured and methane concentration was analyzed using a gas chromatograph. Media were then centrifuged and supernatant drawn off for volatile fatty acid (VFA) concentration analysis, which was performed with a gas chromatograph. IVDMD was determined by filtration and subsequent drying of the filter (140°F) for 48 hours. Data were analyzed using the MIXED procedure of SAS and the model included the fixed effect of treatment.

Table 1. Nutrient content of substrates (% DM; *in vitro* experiment).

	Substrate	
Nutrient content	DDGS	Brome hay
Crude protein	29.5	14.7
Ether extract	9.9	2.4

In vivo methane production

Nine crossbred lambs were assigned randomly to receive a sequence of diets in a replicated 3 X 3 Latin square design. Lambs were offered a control diet (60% brome hay and 30% corn bran; CON), a diet in which the corn bran was replaced with DDGS (60% brome hay and 30% DDGS; DDGS), or a diet in which brome hay was replaced with DDGS (30% brome hay, 30% corn bran, and 30% DDGS; DDGS+BRAN) at 1% of BW as measured at the commencement of the trial. Diet composition and nutrient content is outlined in Table 2. Periods were 14 days with 9 days of adaptation followed by 5 days of collecting orts and feces for determination of DM digestibility. Methane production was determined on days 13 and 14 of each period using the sulfur hexafluoride (SF_6) tracer technique. Prior to the completion of the first period a brass bolus was placed in the rumen of the lambs (via the esophagus). Boluses had been previously filled with SF_6, fit with a Teflon disk to allow for permeation, and monitored for determination of SF_6 release rate (QSF_6). Prior to feeding, each animal was fit with a PVC collection canister that had been preevacuated. Exhaled gas was drawn into the collection canister from 8:00 a.m. to 2:00 p.m. through a capillary tubing and in-line filter that had been attached to a halter. The gas in the canister was analyzed for concentrations of methane ($[CH_4]$) and SF_6 ($[SF_6]$) with separate gas chromatographs equipped with a flame ionization

Table 2. Diet composition and nutrient content (%DM; in vivo experiment).

	Diet		
	CON	DDGS	DDGS+BRAN
Ingredient			
Brome hay	56.0	60.0	30.0
Dried distillers grains	—	30.0	30.0
Corn bran	30.0	—	30.0
Molasses	10.0	10.0	10.0
Soybean meal	4.0	—	—
Mineral	2.0	2.0	2.0
Ammonium chloride	2.0	2.0	2.0
Salt	1.0	1.0	1.0
Nutrient Content			
Crude protein	15.3	18.6	18.8
Ether extract	2.4	5.1	5.2

Table 3. Effects of different DDGS levels on *in vitro* fermentation products.

	DDGS Inclusion (% DM)					
Variable	0	25	50	75	100	SE
CH_4 (µmol)[a]	294[e]	315[e]	287[e]	250[f]	203[g]	10
IVDMD (%)	37.3[e]	39.8[ef]	42.0[f]	46.8[g]	49.2[g]	1.3
CH_4 (µmol/g)[b]	2.68[e]	2.65[e]	2.26[f]	1.82[g]	1.36[h]	0.10
ACT (mmol/g)[c]	6.92[e]	6.97[e]	6.08[e]	4.99[f]	3.91[g]	0.31
PRO (mmol/g)[c]	2.20[e]	2.66[f]	2.85[gf]	2.97[gf]	3.06[g]	0.11
BUT (mmol/g)[c]	0.08[e]	1.06[f]	1.19[f]	1.22[f]	1.11[f]	0.05
VFA (kcal)[d]	2.71	2.99	2.95	2.77	2.52	0.13

[a]Total amount of methane produced by ruminal cultures (µmol).
[b]Amount of methane produced per unit of digested DM (µmol/g).
[c]Amount of individual VFA produced per unit of digested DM (mmol/g).
[d]Energy (kcal) from VFA produced per unit of digested DM calculated as (0.209*ACT)+(0.367*PRO)+(0.524*BUT).
[e,f,g,h]Means within row lacking a common superscript differ (*P*<0.05).

Table 4. Effects of replacing brome hay or bran with DDGS.

	Diet			
Variable	CON	DDGS	DDGS+BRAN	SE
CH_4 (mL/min)	8.24[b]	7.14[b]	5.57[c]	0.76
DM Digestibility (%)	62.7[b]	62.7[b]	68.2[c]	0.8
CH_4 (mL/min • lb)[a]	26.4[b]	21.7[c]	16.4[d]	1.6

[a]CH_4 production rate per lb of digested DM.
[b,c,d]Means within row lacking a common superscript differ (*P*<.05).

detector and electron capture detector, respectively. Methane production rate (QCH_4) was then calculated as follows: $QCH_4 = (QSF_6 * [CH_4]) / [SF_6]$. Data were analyzed using the MIXED procedure of SAS. The model included the fixed effects of square, period, diet, and day of sampling and the random effect of animal. Because the same animal was sampled twice each period a repeated measures covariance structure was used.

Results

In vitro methane production

Inclusion rate of DDGS affected the total amount of methane produced by ruminal cultures resulting in a quadratic (*P*<0.05) response (Table 3). Cultures containing 0% DDGS produced more (*P*<0.05) methane than those containing 100% DDGS. IVDMD increased linearly (*P*<0.05) and methane production per milligram of digested DM decreased linearly (P<0.05) as the inclusion rate of DDGS was increased.

Acetate production per unit of digested matter decreased in a quadratic (P< 0.05) fashion as DDGS replaced brome hay. Cultures containing 0% DDGS (100% brome hay) produced 176% more (*P*<0.05) acetate per unit of digested DM than did cultures containing 100% DDGS. Propionate production per unit of digested DM increased linearly (*P*<0.05) as DDGS inclusion was increased. Cultures containing 0% DDGS produced 28% less (*P*<0.05) propionate per unit of digested DM than did cultures containing 100% DDGS. Butyrate concentrations increased in a quadratic (*P*< 0.05) fashion as DDGS inclusion rate was increased. Cultures containing 0% DDGS produced 23% less (*P*<0.05) butyrate per g of digested DM as compared to cultures containing 100% DDGS. The kcal of energy available from the VFAs produced per unit of digested DM ranged from 2.52 to 2.99 kcal but this response variable was not affected by DDGS inclusion rate. Therefore, the reduction in methane observed in vitro when brome hay is replaced with DDGS does not affect the amount of energy produced in the form of VFAs.

In vivo methane production

When lambs received the DDGS+BRAN methane production rates were reduced by 30% compared to the CON diet, and reduced by 20% compared to the DDGS diet (Table 4). No difference was detected in methane production rates when comparing the CON diet to the DDGS diet. Therefore, replacement of brome with DDGS reduced methane production but replacement of corn bran with DDGS did not affect methane production. These data indicate the addition of only the bran component of dried distillers grains (DDGS vs. DDGS+BRAN) may be partially responsible for this reduction in methane production, while addition

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of the nonfiber component (CON vs. DDGS) had less effect on methane production. Addition of the whole product (CON vs. DDGS+BRAN) resulted in the greatest reduction. We conclude that the effect DDGS has on methane production is not limited to solely the corn bran component or the non-fiber component but is a combination of the two.

Dry matter digestibility was greater ($P<0.05$) for the DDGS+BRAN diet than for either the CON or DDGS diet, which were not different. Methane production rate per unit of digested DM was different for all dietary treatments. DDGS+BRAN decreased methane production by 38% compared to the CON diet and by 24% compared to the DDGS diet. DDGS decreased methane production per unit of digested DM by 18% compared to the CON diet. The effect of DDGS on methane production rate per unit of digested DM indicates that independent of the amount of dry matter fermented, DDGS decreases ruminal methane production.

Both *in vitro* and *in vivo*, replacement of brome hay with DDGS decreased methane production. The amount of energy produced in the form of VFAs was not affected by increasing concentrations of DDGS in vitro. The enhanced ADG despite decreased DMI that is realized when forage in cattle diets is replaced with DDGS may be partially attributed to less feed energy being lost as methane.

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