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# Effects of Dietary Fat Source and Monensin on Methane Emissions, VFA Profile, and Performance of Finishing Steers

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## Summary

*A finishing study was conducted to evaluate the effects of dietary fat source and presence or absence of monensin on performance, methane ($CH_4$) emissions, and ruminal VFA profile of cattle. No effects on performance or VFA profile were observed. Inclusion of modified distillers grain plus solubles (MDGS) in the diet tended to increase measures of $CH_4$ production when compared to other fat sources (corn oil or tallow), while inclusion of monensin in the finishing diet was not significant for $CH_4$ production.*

## Introduction

Interest in emissions of methane and other greenhouse gasses by livestock has increased. Livestock account for only 3.6% of greenhouse gas emissions in the U.S. or about one-third of all agriculture sources. Methane contributes to total greenhouse gas emissions, and cattle account for 20% of U.S. methane. Despite the relatively small contribution of methane from cattle to total emissions, this issue represents a situation where environmental concerns and animal productivity intersect, as the production of methane represents an energetic loss to the animal. Diet is one of the main determinants of methane production, thus prompting recent work evaluating nutritional mitigation strategies. However, much of this work has been conducted on a small scale using intensive techniques such as respiration chambers or headboxes. Therefore, the development of a method of gas collection and analysis to allow evaluation of methane emissions from a relatively large number of animals under conditions that more closely mimic a production setting would be beneficial. The objective of this study was to evaluate the effect of the source of dietary fat and the presence or absence of monensin on performance, methane production, and VFA profile in finishing cattle.

**Table 1. Composition of diets that contain 0 or 50% MDGS[1], with or without monensin; as well as differing sources of fat (DM basis).**

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | CON + | CON - | MDGS + | MDGS - | OIL | TAL |
| Monensin | Y | N | Y | N | Y | Y |
| DRC[2] | 87 | 87 | 37 | 37 | 84 | 84 |
| MDGS | — | — | 50 | 50 | — | — |
| Sorghum silage | 8 | 8 | 8 | 8 | 8 | 8 |
| Corn oil | — | — | — | — | 3 | — |
| Tallow | — | — | — | — | — | 3 |
| Supplement[3] | 5 | 5 | 5 | 5 | 5 | 5 |

[1]MDGS = modified distillers grains plus solubles.
[2]DRC = dry-rolled corn.
[3]Formulated to contain 375 mg/head/day monensin and 90 mg/head/day Tylan.

## Procedure

A 125-day finishing study was conducted using 60 crossbred steers (initial BW = 913 ± 35 lb) that were individually fed using the Calan gate system. Five days before trial initiation, cattle were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran® at 2% of BW to reduce variation in gut fill and then weighed on three consecutive days, with the average used as initial BW. Steers were stratified by initial BW from day -1 and day 0, and assigned randomly to one of six treatments (Table 1), with 10 steers per treatment. A completely randomized design of four diets were used to compare sources of dietary fat: a corn-based control with no added fat (CON), a diet with 50% modified distillers grains plus solubles (MDGS), and two corn-based diets with either 3% corn oil (OIL) or 3% tallow (TAL), all containing 375 mg/head/day monensin. Two additional diets were added to create a 2×2 factorial that consisted of either 0 or 50% MDGS and 0 or 375 mg/head/day monensin. The MDGS, OIL, and TAL diets were formulated to provide 6.5% total dietary fat. Steers were implanted with Revalor®-S on day 1. On day 125, cattle were individually weighed and transported to a commercial abattoir (Greater Omaha Packing, Omaha, Neb.) to be harvested. Hot carcass weight (HCW) and liver abscess scores were collected on day of slaughter. Following a 48-hour chill, 12$^{th}$-rib fat thickness, LM area, and USDA marbling score were recorded. Carcass adjusted final BW, ADG, and F:G were calculated using HCW and a common 63% dressing percentage.

To facilitate the collection of respired air by the cattle to be analyzed for methane and carbon dioxide, the individual Calan gate bunks were partially enclosed and outfitted with a small air pump that was used to gradually fill a gas collection bag. Gas collection was conducted at time of feeding, and gas sample bags were filled with air at a constant rate over approximately 10 minutes. Gas samples were collected only while steers were in their bunks. The collected gas consisted of a mixture of respired gasses and ambient air and was analyzed within 24 hours for concentration of methane and carbon dioxide in ppm using a gas chromatograph. Methane data are expressed as a ratio of methane to carbon dioxide ($CH_4$:$CO_2$) where $CO_2$ can be used as an internal marker since its production is relatively constant across cattle of

(Continued on next page)

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similar size, type, and production level. Gas samples were collected from each steer approximately once per week throughout the feeding period. Volatile fatty acid profile was evaluated using rumen fluid collected via esophageal tubing on day 55, prior to feeding. A portion of rumen fluid was also frozen and stored at -80° C for rumen microbial community analysis.

Estimates of daily $CH_4$ and $CO_2$ production as well as liters of $CH_4$ per lb of intake and gain were made using the equation of Madsen, et al., (*Livestock Science* 2010, pp. 223-227). This method uses measured $CH_4$:$CO_2$, calculated diet TDN, and observed DMI, and ADG to determine methane production. The equation proposed by these authors considers any metabolizable energy that is not used for gain to be lost as heat. Since heat production and $CO_2$ production are closely linked, and we are able to measure $CH_4$:$CO_2$, we can calculate useful measures of $CH_4$ production to compare across animals and diets.

Performance, VFA, and emissions data were analyzed with the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) using preplanned contrasts and steer as the experimental unit. Methane to carbon dioxide ratio was analyzed using the heterogeneous compound symmetry covariance structure with sampling point as the repeated measure.

## Results

### *Performance*

No differences ($P > 0.10$) were observed for any performance or carcass traits due to dietary fat source (Table 2) or monensin (Table 3). The lack of difference between diets with added fat (MDGS, OIL, and TAL) is likely due to the similar energy content of those diets, as each was formulated to contain 6.5% dietary fat. However, it is surprising to observe no difference between 0 and 50% MDGS or the presence or absence of monensin, as these effects have been long established.

**Table 2. Effect of source of dietary fat in the finishing diet on performance and carcass characteristics.**

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | CON | MDGS | OIL | TAL | SEM | *P*-value |
| Performance | | | | | | |
| Initial BW, lb | 923 | 922 | 903 | 892 | 33.5 | 0.89 |
| Final BW, lb[2] | 1364 | 1363 | 1372 | 1310 | 39.5 | 0.67 |
| DMI, lb | 24.8 | 24.3 | 24.4 | 23.3 | 0.6 | 0.37 |
| ADG, lb[2] | 3.53 | 3.53 | 3.75 | 3.35 | 0.17 | 0.43 |
| F:G[2] | 7.03 | 6.91 | 6.49 | 6.54 | | 0.47 |
| Carcass Characteristics | | | | | | |
| HCW, lb | 860 | 859 | 864 | 825 | 24.9 | 0.67 |
| Dressing % | 61.6 | 62.3 | 62.6 | 61.1 | 0.60 | 0.33 |
| LM area, in$^2$ | 13.6 | 13.2 | 12.7 | 12.9 | 0.33 | 0.36 |
| 12$^{th}$ rib fat, in | 0.51 | 0.65 | 0.56 | 0.54 | 0.05 | 0.19 |
| Calculated YG | 3.21 | 3.62 | 3.58 | 3.35 | 0.18 | 0.32 |
| Marbling score[3] | 465 | 438 | 412 | 406 | 24.4 | 0.30 |

[1]Treatments included: a corn-based diet with no added fat (CON), 50% modified distillers grains plus solubles (MDGS), and a corn-based diet with either 3% corn oil (OIL) or 3% tallow (TAL).
[2]Calculated from HCW, adjusted to a common 63% dressing percentage.
[3]Marbling score: 400 = Small00.

**Table 3. Effect of diet type and presence of monensin on finishing performance and carcass characteristics.**

| | 0 MDGS | | 50 MDGS | | | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| Monensin | Y | N | Y | N | SEM | Diet | Mon | D *M |
| Performance | | | | | | | | |
| Initial BW, lb | 923 | 926 | 922 | 909 | 35.0 | 0.79 | 0.88 | 0.81 |
| Final BW, lb[2] | 1364 | 1357 | 1363 | 1392 | 41.5 | 0.67 | 0.78 | 0.65 |
| DMI, lb | 24.8 | 24.0 | 24.3 | 25.4 | 0.77 | 0.56 | 0.86 | 0.22 |
| ADG, lb[2] | 3.53 | 3.45 | 3.53 | 3.88 | 0.19 | 0.26 | 0.48 | 0.26 |
| F:G[2] | 7.03 | 6.89 | 6.91 | 6.54 | | 0.48 | 0.43 | 0.71 |
| Carcass Characteristics | | | | | | | | |
| HCW, lb | 860 | 855 | 859 | 878 | 26.2 | 0.67 | 0.78 | 0.65 |
| Dressing % | 61.6 | 62.0 | 62.3 | 62.6 | 0.61 | 0.30 | 0.52 | 0.90 |
| LM area, in$^2$ | 13.6 | 13.5 | 13.2 | 13.6 | 0.36 | 0.69 | 0.60 | 0.50 |
| 12$^{th}$ rib fat, in | 0.51 | 0.60 | 0.65 | 0.59 | 0.05 | 0.18 | 0.73 | 0.13 |
| Calculated YG | 3.21 | 3.42 | 3.62 | 3.46 | 0.18 | 0.21 | 0.89 | 0.29 |
| Marbling score[3] | 465 | 410 | 438 | 463 | 26.1 | 0.60 | 0.53 | 0.11 |

[1]*P*-value: Diet = main effect of diet (0 or 50% MDGS), Mon = main effect of presence of Monensin, D*M = effect of interaction between diet type and monesin.
[2]Calculated from HCW, adjusted to a common 63% dressing percentage.
[3]Marbling score: 400 = Small00.

**Table 4. Effect of source of dietary fat in the finishing diet on methane production and VFA profile.**

| | Treatment[1] | | | | | |
|---|---|---|---|---|---|---|
| | CON | MDGS | OIL | TAL | SEM | *P*-value |
| $CH_4$:$CO_2$ | 0.047$^b$ | 0.058$^a$ | 0.054$^{a,b}$ | 0.049$^b$ | 0.003 | 0.07 |
| L $CH_4$/day[2] | 227 | 270 | 249 | 221 | 18 | 0.21 |
| L $CO_2$/day[2] | 4774 | 4654 | 4633 | 4521 | 130 | 0.60 |
| L $CH_4$/lb DMI[2] | 9.1 | 11.1 | 10.1 | 9.5 | 0.6 | 0.13 |
| L $CH_4$/lb ADG[2] | 64.1 | 78.8 | 67.2 | 67.6 | 5.5 | 0.27 |
| Total VFA, Mm | 131.3 | 135.5 | 179 | 108 | 35.2 | 0.55 |
| Acetate, mol/100 mol | 45.2 | 48.5 | 45.1 | 46.4 | 1.9 | 0.57 |
| Propionate, mol/100 mol | 40.3 | 36.4 | 42.7 | 39.9 | 2.1 | 0.22 |
| Butyrate, mol/100 mol | 8.1 | 8.2 | 6.1 | 7.3 | 1.1 | 0.45 |
| Acetate:Propionate | 1.21 | 1.40 | 1.08 | 1.20 | 0.13 | 0.42 |

[1]Treatments included: a corn-based diet with no added fat (CON), 50% modified distillers grains plus solubles (MDGS), and a corn-based diet with either 3% corn oil (OIL) or 3% tallow (TAL).
[2]Values were calculated using equation of Madsen et al., 2010.
[a,b]Means in a row with different superscripts are different ($P < 0.10$).


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**Table 5. Effect of diet type and presence of monensin on methane production and VFA profile.**

| | 0 MDGS | | 50 MDGS | | | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|
| Monensin | Y | N | Y | N | SEM | Diet | Mon | D *M |
| $CH_4$:$CO_2$ | 0.047 | 0.053 | 0.058 | 0.056 | 0.003 | 0.03 | 0.56 | 0.19 |
| L $CH_4$/day[2] | 227 | 247 | 270 | 260 | 18 | 0.12 | 0.77 | 0.41 |
| L $CO_2$/day[2] | 4774 | 4610 | 4654 | 4780 | 167 | 0.87 | 0.90 | 0.37 |
| L $CH_4$/lb DMI[2] | 9.1 | 10.2 | 11.1 | 10.2 | 0.6 | 0.10 | 0.81 | 0.11 |
| L $CH_4$/lb ADG[2] | 64.1[b] | 74.4[a,b] | 78.8[a] | 68.0[a,b] | 6.2 | 0.49 | 0.97 | 0.08 |
| Total VFA, Mm | 131.3 | 109.2 | 135.5 | 121.0 | 35.1 | 0.81 | 0.59 | 0.91 |
| Acetate, mol/100 mol | 45.2 | 44.1 | 48.5 | 45.3 | 1.9 | 0.23 | 0.24 | 0.57 |
| Propionate, mol/100 mol | 40.3 | 41.7 | 36.4 | 40.2 | 2.1 | 0.20 | 0.20 | 0.56 |
| Butyrate, mol/100 mol | 8.1 | 7.3 | 8.2 | 7.6 | 1.0 | 0.85 | 0.46 | 0.91 |
| Acetate:Propionate | 1.21 | 1.10 | 1.40 | 1.14 | 0.12 | 0.34 | 0.12 | 0.56 |

[1]*P*-value: Diet = main effect of diet (0 or 50% MDGS), Mon = main effect of presence of monensin, D*M = effect of interaction between diet type and monensin.
[2]Values were calculated using equation of Madsen et al., 2010.
[a,b]Means in a row with different superscripts are different ($P < 0.10$).

*Emissions*

Average measured $CH_4$:$CO_2$ throughout the finishing period was greatest for cattle fed MDGS, lowest for those fed CON and TAL, with OIL being intermediate ($P = 0.07$; Table 4). This increase in $CH_4$ with MDGS may reflect the greater concentration of digestible fiber in that diet. The rationale behind supplying different fat sources is that unsaturated fat provides a hydrogen sink in the rumen, which should, in turn, reduce the production of methane as a means of disposing of hydrogen, as well as the idea that fat may be detrimental to methanogens. We hypothesized that cattle fed OIL would have a lower $CH_4$:$CO_2$ than those fed TAL due to the differences in degree of saturation of those fats. However a higher inclusion in the diet may have been necessary to see the full impact of that mechanism of hydrogen sink. Neither daily $CH_4$ nor $CO_2$ production were different due to fat source ($P = 0.21$ and 0.60, respectively). Dry matter intake is a main determinant of $CH_4$ production, so it is useful to calculate L $CH_4$/lb DMI, and there was a tendency for cattle fed MDGS ($P = 0.13$) to have the greatest $CH_4$/lb DMI, while there was no difference between CON, OIL, and TAL diets. Since there were no differences observed for ADG or F:G, again no differences were observed for L $CH_4$/lb ADG, ($P = 0.27$). We did not observe differences in $CH_4$ due to fat inclusion in this study, but rather the increased $CH_4$ production by cattle fed MDGS may presumably be in response to elevated digestible fiber content. However, fat and protein are metabolized more efficiently than carbohydrate and may produce less $CO_2$. Therefore, replacing corn (starch) with MDGS or fat sources may have reduced $CO_2$ production. This would increase the methane:$CO_2$ ratio and result in overestimation of methane production. Further emissions and digestibility work is planned to confirm this hypothesis.

A basal diet × monensin interaction was observed for L $CH_4$/lb ADG ($P = 0.08$; Table 5), where the addition of monensin to a diet containing 50% MDGS increased $CH_4$, but decreased $CH_4$ when included in a corn-based diet. Again, there were no corresponding differences in performance due to monensin, so this is mostly a reflection of the main effect that basal diet had on $CH_4$:$CO_2$ ($P = 0.03$). This main effect of inclusion of 0 vs. 50% MDGS was also observed as a tendency for greater daily $CH_4$ production ($P = 0.12$) as well as L of $CH_4$/lb DMI ($P = 0.10$) for cattle fed MDGS, while no effect due to monensin ($P > 0.56$) was observed. While ionophores may be expected to reduce $CH_4$ production due to their expected effects on VFA profile, this lack of response is not necessarily surprising, as the data on the impact of monensin on $CH_4$ have been inconsistent.

*VFA Profile*

No effects of dietary fat source on VFA profile ($P > 0.22$; Table 4) and only a tendency ($P = 0.12$) for monensin to increase acetate to propionate ratio, contrary to expectation, were observed. We hypothesized that a shift in $CH_4$ production due to diet would also be seen as a shift in VFA profile; generally away from acetate and towards production of propionate, another hydrogen sink. However, these data are from one sampling time point at the time of feeding, which may not be optimal for observing the effect that diet has on VFA profile.

These data do not support the idea that differences in saturation of a dietary fat source affect $CH_4$ production in finishing diets with a total dietary fat of 6.5%. The effect of MDGS is complex, as the feed's fat and fiber components have conflicting implications for $CH_4$ production. In this study, DMI and fat content were constant, suggesting that the effect on $CH_4$ is driven more by the elevated digestible fiber content of MDGS. The diet × monensin interaction on L $CH_4$/lb ADG is difficult to explain but, on the whole, the inclusion of monensin did not affect $CH_4$ production. The method described in this article to calculate methane production from methane to carbon dioxide ratio is but one approach that can be used, and work is ongoing to develop a more complete model for predicting methane emissions.

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