# Methane Emissions from Beef Cattle

Subjects: Zoology

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Methane is a potent greenhouse (GHG) gas 28 times more potent than CO2 in producing global warming. Methane (CH4) is produced naturally by beef cattle during the fermentation and digestion of their diet, and most of it is belched to the atmosphere. In 2005 cattle emitted 4.6 gigatonnes CO2 equivalent, from which 2.5 gigatonnes originated from beef and 2.1 gigatonnes from dairy cattle, whereas small ruminants and buffalos emitted 0.47 and 0.62 gigatonnes CO2 equivalents, respectively. Thus, cattle contributed about 9.4% of the total global anthropogenic greenhouse gas emissions, methane included, in 2005. Ruminant nutritionists have developed different strategies, which include the use of antibiotics, plant secondary metabolites such as tannins, and other chemical compounds, like nitrate, to manipulate rumen fermentation and reduce CH4 emissions and climate change. Mitigating GHGs such as methane (CH4) originating from the beef cattle industry, offers an opportunity to reduce GHG emissions and climate change over the short term.

Further, for the last two decades, scientists have been evaluating the potential of natural feed additives such as herbs and plant extracts, which have also been used for centuries for various purposes in human diets. So, the purpose of this entry is to demonstrate the in vivo the antimethanogenic effects of *Cymbopogon citratus*, *Matricaria chamomilla* and *Cosmos bipinnatus* in beef cattle fed a finishing diet high in concentrates (forage:concentrate (F:C) ratio of 19.4:80.6) and the effects of increasing supplementation levels of C. citratus, i.e., 0%, 2%, 3% and 4% of the daily DMI, on enteric CH4 emissions from beef cattle fed a total mixed ration (TMR) with an F:C ratio of 50.7:49.3.

Keywords: beef cattle ; enteric methane ; mitigation ; herbs ; lemongrass

## 1. Introduction

There is growing concern worldwide regarding the role that domestic ruminants play in global warming and climate change. Domestic ruminants produce large amounts of greenhouse gases (GHGs), such as methane ($CH_4$), which originates from enteric fermentation and the degradation of feces [1][2]. According to the Environmental Protection Agency of the United States of America [3], in 2018, global $CH_4$ production from enteric fermentation represented 28% of the methane emitted globally by the agricultural, forestry and other land-use (AFOLU) sector. The AFOLU sector represents 24% of the total GHGs emitted globally.

The United States is the largest producer of beef worldwide and, as a result, beef and dairy cattle contribute to approximately 48% of the US agricultural GHG emissions reported in 2015 [4][5]. Methane is produced in large volumes by cattle, e.g., up to 716 g/d for a dairy cow [6] and up to 372 g/d for beef cow [7]. This gas is 28 times more powerful than $CO_2$ in terms of its capacity to cause the greenhouse effect; however, its lifespan in the atmosphere ranges from only 9 to 15 years [2]. The short lifespan of $CH_4$ means that it may be possible to mitigate climate change more rapidly by reducing enteric $CH_4$ emissions than by reducing $CO_2$ emissions because the $CO_2$ can remain in the atmosphere for up to 200 years. Therefore, mitigating the $CH_4$ from cattle offers an opportunity to reduce GHG emissions and climate change.

Ruminant nutritionists have developed different strategies, which include the use of antibiotics and plant secondary metabolites and other chemical compounds, such as nitrate, to manipulate rumen fermentation, and reduce $CH_4$ and nitrogen (N) emissions [8][9]. It is well known that the use of synthetic antibiotics, e.g., monensin, as feed additives is a useful way to reduce energy losses in the form of $CH_4$ in ruminants [10]. For example, according to Appuhamy et al. [11], monensin supplementation reduces $CH_4$ emissions by 15% in beef cattle. However, such use of antibiotics has caused public concern because of the presence of residues in milk and beef and the increasing resistance of microbes to treatment with antibiotics. Thus, the use of antibiotics for this purpose is banned in some countries. For the last two decades, scientists have been evaluating the potential of natural feed additives such as herbs and plant extracts, which have also been used for centuries for various purposes in human diets. Herbs such as garlic [12] and oregano [13], have been shown to modulate rumen fermentation, improve nutrient utilization, and reduce $CH_4$ production in ruminants.

Similarly, lemongrass (*Cymbopogon citratus*) and peppermint (Mentha × piperita), when used as feed additives alone or in combination, have been reported to improve production performance and rumen fermentation efficiency in terms of microbial cell synthesis and VFA production, and reduce $CH_4$ production [14].

Furthermore, Wanapat et al. [15] demonstrated that 100 g/d *Cymbopogon citratus* (CC) powder enhanced the digestibility of nutrients, the rumen microbial community (by increasing cellulolytic and amylolytic bacteria), and microbial protein synthesis efficiency, thus improving rumen ecology in beef cattle. However, the antimethanogenic effect of CC was not measured in respiration chambers by Wanapat et al. [14], it was estimated on the basis of the VFAs concentration in rumen liquor. Thus, it is necessary to evaluate the antimethanogenic properties of CC and its potential as an antimethanogenic herb in vivo. This herb has been used for many years in folk medicine because of its antiseptic, antifever, antidyspeptic, antioxidant, antinociceptive, carminative and anti-inflammatory effects [16]. It also has febrifuge, analgesic, spasmolytic, antipyretic, diuretic, tranquilizer and stomachic properties [16], but its antimethanogenic properties have not been evaluated in vivo.

Similarly, herbs such as *Cosmos bipinnatus* (CB), a Mexican Asteraceae, have shown antimethanogenic properties in vitro [17] and in vivo in dairy cattle [18] but have never been tested in beef cattle, particularly those fed diets with high concentrate levels. Additionally, plants such as *Matricaria chamomilla* [MC] have never been evaluated in vivo, despite their high contents of flavonoids and other phenolic compounds, which have been identified in various parts of the MC flower [19]. Flavonoids such as quercetin have been shown to reduce the total population of protozoa and methanogens. In the case of methanogenic bacteria, flavonoids inhibit the synthesis of the bacterial cell wall, the cytoplasmic membrane, and nucleic acid synthesis, which is reflected in a decrease in $CH_4$ production [20]. Using real-time PCR amplification, Oskoueian et al. [20] demonstrated that naringin and quercetin significantly reduced the total population of ruminal protozoa by reducing the efficiency of protozoa protein synthesis. Additionally, flavonoids improve fermentation efficiency by increasing propionate production to the detriment of acetate production, thus decreasing the population of methanogenic archaea. Using the in vitro gas production technique, Petrič et al. [19] investigated the effects of four individual medicinal plants, namely, wormwood, chamomile, fumitory, and mallow, and their mixture used as dietary substrates on ruminal and intestinal fermentation parameters, the total ciliate protozoan population, and total antioxidant capacity of rumen fluid. The authors concluded that the mixture of wormwood, chamomile, fumitory and mallow possessed a strong ruminal antioxidant capacity and showed the potential to reduce ruminal and intestinal $CH_4$ emissions and ammonia concentrations.

Therefore, the objectives of the present work were to evaluate in vivo the antimethanogenic effects of *C. citratus*, *M. chamomilla* and *C. bipinnatus* in beef cattle fed a finishing diet high in concentrates (forage:concentrate (F:C) ratio of 19.4:80.6) and the effects of increasing supplementation levels of *C. citratus*, i.e., 0%, 2%, 3% and 4% of the daily DMI, on enteric $CH_4$ emissions from beef cattle fed a total mixed ration (TMR) with an F:C ratio of 50.7:49.3. The doses of the supplemented plants were based on the antimethanogenic effects observed in previous experiments. For example, the dose of 365 g DM/d recommended by Hernández-Pineda et al. [18] was used for CB because a significant reduction in daily $CH_4$ production at this dose was reported by the authors.

## 2. Results

Table 1 shows the effects of experimental herb supplementation on DMI, GE intake (GEi), the digestibilities of DM (DigDM), NDF (DigNDF), ADF (DigADF) and GE (DigGE); and the variables related to the enteric $CH_4$ emissions in Experiment 1. There were no significant effects ($p > 0.05$) on DMI, DigDM, DigNDF, DigADF, DigGE or average daily $CH_4$ production. However, significant differences ($p < 0.05$) in methane yield (g of $CH_4$/kg of DMI), ADWG, the methane conversion factor known as the *Ym* factor (energy of $CH_4$ as a percentage of GEi), and $CH_4$ emission intensity (g of $CH_4$/kg of ADWG) were observed. The lowest $CH_4$ yields ($p < 0.05$) were observed in the CC and CB treatments, where they were 33% and 28% lower than those in the CO treatment, respectively. The lowest $CH_4$ emission intensity (g of $CH_4$/kg of ADWG) was observed in the CB treatment, followed by the CC treatment; similarly, the smallest values of the *Ym* factor were observed in the CC and CB treatments, where they differed significantly ($p < 0.05$) from those in the CO and MC treatments. Supplementation with CB resulted in a significantly higher ($p = 0.03$) ADWG than that observed in the other treatments. The third highest LW gain was observed in the CC treatment, but this value was not significantly different ($p > 0.05$) from that obtained under the CO treatment.

**Table 1.** Effects of *Matricaria chamomilla*, *Cosmos bipinnatus* and *Cymbopogon citratus* supplementation on dry matter intake, digestibility, live weight gain and methane production in F1 beef steers on a finishing diet in Experiment 1.

| Treatments | | | | | SEM | p-Value |
|---|---|---|---|---|---|---|
| | CO | MC | CB | CC | | |
| **DMI (kg/d)** | **7.92** | **8.66** | **10.3** | **9.63** | **0.93** | **0.109** |
| **LW (kg)** | **390** | **373** | **395** | **392** | **21.8** | **0.196** |
| **DMI (%LW)** | **2.10** | **2.31** | **2.60** | **2.41** | **0.15** | **0.159** |
| **DigDM (%)** | **78.5** | **82.5** | **82.8** | **77.9** | **2.61** | **0.471** |
| **DigNDF (%)** | **80.6** | **83.0** | **79.7** | **83.2** | **2.09** | **0.455** |
| **DigADF (%)** | **64.0** | **64.2** | **56.9** | **59.7** | **3.56** | **0.484** |
| **DigGE (%)** | **78.6** | **84.1** | **84.4** | **80.2** | **2.37** | **0.210** |
| **ADWG (kg/d)** | **1.43 [ab]** | **0.88 [b]** | **1.81 [a]** | **1.29 [ab]** | **0.21** | **0.029** |
| **$CH_4$ (g/d)** | **128** | **124** | **118** | **107** | **13.30** | **0.700** |
| **$CH_4$ (g/kg of DMI)** | **16.3 [a]** | **14.3 [ab]** | **11.8 [b]** | **11.0 [b]** | **1.08** | **0.009** |
| **$CH_4$ (g/kg ADWG)** | **132 [a]** | **149 [a]** | **67.5 [b]** | **103 [ab]** | **20.5** | **0.028** |
| ***Ym* (%)** | **5.02 [a]** | **4.41 [ab]** | **3.62 [b]** | **3.38 [b]** | **0.33** | **0.009** |
| **GEi (MJ/d)** | **142** | **155** | **184** | **173** | **16.7** | **0.112** |
| **DEi (MJ/d)** | **113** | **131** | **157** | **143** | **16.7** | **0.136** |

Table 2 shows the results for Experiment 2, where increasing supplementation levels of CC were evaluated. No significant differences were observed for DMI, ADWG, $CH_4$ yield, *Ym* factor or $CH_4$ emission intensity ($p > 0.05$). Significant declines (linear $p < 0.05$; quadratic $p < 0.05$) in total daily $CH_4$ production were observed at the 2% and 3% CC supplementation levels, and a numerical reduction was observed at the 4% inclusion level, with 26%, 26.2% and 15% less $CH_4$ produced, respectively, than in the CO treatment. Numerical differences were observed for $CH_4$ yield at the 2% and 3% supplementation levels, where the yield was 12% and 15% less, respectively, than that in the CO treatment. A significant reduction (linear $p < 0.05$; quadratic $p = 0.04$) in DigDM at the 3% CC inclusion level was observed, but no effects were observed at the other two levels for this variable. However, DigNDF and DigADF declined as the supplementation level of CC increased in comparison with the CO treatment ($p < 0.05$). The declines in DigNDF (linear $p = 0.02$; quadratic $p = 0.002$) and DigADF (linear $p = 0.02$; quadratic $p = 0.01$) at 3% CC were accompanied by a significant reduction ($p < 0.05$) in total daily methane emissions in g/d, suggesting that the CC effect on $CH_4$ production was dose-dependent. Therefore, the 2% CC treatment reduced total methane emissions by 26% without affecting DigDM or ADWG. In contrast, the reduction in total daily $CH_4$ emission at the 3% CC supplementation level was associated with decreases in the digestibility of DM, NDF and ADF. However, this pattern was not repeated at the 4% inclusion level because supplementation with CC at this level reduced total daily $CH_4$ emissions only numerically, with no effect on DigDM ($p >$ 0.05) We observed numerical declines ($p > 0.05$) in the *Ym* factor in association with supplementation of CC, particularly at the 2% (*Ym* = 5.9) and 3% (*Ym* = 5.8) inclusion levels, in comparison with the CO treatment (*Ym* = 7.0) (Table 2).

**Table 2.** Effects of increasing levels of *Cymbopogon citratus* supplementation on dry matter intake, digestibility, live weight gain and methane production in F1 beef steers fed a total mixed ration in Experiment 2.

| Experimental Diets | | | | | SEM | p-Value | Statistical Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | CO | 2% CC | 3% CC | 4% CC | | | L | Q | C |
| **DMI (kg/d)** | **16.0** | **14.0** | **13.7** | **14.3** | **1.41** | **0.666** | **NS** | **NS** | **NS** |
| **LW (kg)** | **508** | **507** | **513** | **511** | **3.41** | **0.647** | **NS** | **NS** | **NS** |
| **DMI (%LW)** | **3.16** | **2.81** | **2.69** | **2.79** | **0.24** | **0.602** | **NS** | **NS** | **NS** |
| **DigDM (%)** | **76.2** | **69.9** | **65.5** | **72.2** | **2.46** | **0.050** | **0.05** | **0.04** | **NS** |
| **DigNDF (%)** | **71.8** | **65.2** | **54.9** | **66.6** | **1.73** | **0.003** | **0.02** | **0.002** | **0.02** |
| **DigADF (%)** | **71.1** | **63.8** | **56.0** | **64.7** | **1.86** | **0.007** | **0.02** | **0.01** | **NS** |
| **DigGE (%)** | **77.7** | **73.1** | **66.9** | **76.6** | **1.25** | **0.003** | **NS** | **0.001** | **0.02** |

| Experimental Diets | | | | | SEM | p-Value | Statistical Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | CO | 2% CC | 3% CC | 4% CC | | | L | Q | C |
| ADWG (kg/d) | 1.16 | 1.01 | 1.10 | 1.20 | 0.92 | 0.561 | NS | NS | NS |
| $CH_4$ (g/d) | 308 | 228 | 227 | 261 | 22.9 | 0.050 | 0.05 | 0.05 | NS |
| $CH_4$ (g/kg of DMI) | 20.0 | 17.6 | 16.9 | 19.9 | 1.21 | 0.262 | NS | NS | NS |
| $CH_4$ (g/kg ADWG) | 291 | 230 | 236 | 252 | 29.5 | 0.511 | NS | NS | NS |
| *Ym* (%) | 7.03 | 5.94 | 5.83 | 6.60 | 0.38 | 0.197 | NS | NS | NS |
| GEi (MJ/d) | 252 | 219 | 215 | 224 | 22.1 | 0.656 | NS | NS | NS |
| DEi (MJ/d) | 197 | 161 | 144 | 172 | 17.5 | 0.285 | NS | NS | NS |

It was concluded that *Cosmos bipinnatus* and *Cymbopogon citratus* decreased *in vivo* methane production by beef cattle; the effects on $CH_4$ production were dependent on diet and the dose and tannin content of these herbs. On the contrary, no antimethanogenic effect was observed by chamomile. On the other hand, these herb effects on animal performance in both experiments and on digestibility in Experiment 1 should be considered preliminary as more research is necessary. It is also concluded that supplementation of Cymbopogon citratus at levels above 190 g DM/d can reduce daily $CH_4$ production but at the expense of reducing the digestibility of DM, and fiber fractions of diets. To the best of our knowledge, this was the first study in which the response of $CH_4$ production to C. citratus supplementation was measured in vivo.

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