Methane Emissions of Beef Cattle on Forages: Efficiency of Grazing Management Systems

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The methane (CH_4) produced from enteric fermentation by domesticated livestock is estimated to contribute 21% of total U.S. anthropogenic emissions of "greenhouse gas," with cattle contributing 95% of total livestock emissions. Methane produced by enteric fermentation in grazing cattle is seen as a strong contributor to various climate change scenarios associated with global warming. The possibility of limiting CH_4 emissions from beef cattle by improving grazing management systems provides economic as well as environmental benefits. The best strategy for mitigation of cattle CH_4 is probably through enhancing the efficiency of feed energy use.

About half of the beef cows in the U.S. are located in the South. These operations have frequently revealed low profit potential. Studies have shown that income from calf sales is low because total calf production may be as low as 70 kg ha^{-1} annually. Cow–calf production systems in the southern U.S. are based primarily on forages. Most of these systems consist of warm-season perennial grasses during much of the grazing season. During most of that time, however, the dominant, warm-season perennial grasses, which are introduced species, lack sufficient quality for maximum sustained weight gain. It is speculated the genetic production potential of most cow herds is limited by the lack of, or management for, adequate amounts of high-quality forage. Average weaning weights of 150 to 200 kg for calves in many southern states show lack of proper forage management. In addition, in Louisiana these warm-season forages are harvested for hay when they are rather mature and of low quality and are fed to most beef cattle herds for maintenance during the winter. The long growing season allows extensive grazing of the forage, which is a more efficient means of harvesting. With controlled-rotation grazing management or management-intensive grazing (MIG) systems, the potential exists to maximize both forage and beef production and increase the efficiency of beef production.

The objectives of this project were to determine and demonstrate methods for improving beef production per unit of methane emission, and to measure the productivity of beef cattle grazing different adapted forages under traditional and improved management systems.

MATERIALS AND METHODS

The sulfur hexafluoride (SF_6) tracer method for measuring eructated CH_4 was used in this study. It involves placing a small brass permeation tube, with a known permeation rate of SF_6, in the reticulum. Cattle were raised and maintained under the same conditions used in commercial beef cattle production in the area.

In October 1996, both cows and heifers were blocked on weight and age at the beginning of the experiment and assigned to either the treatment or control group. "Tester" animals in each of the two herds included six yearling heifers with an average weight of 390 kg and six cows with an average weight of 540 kg that had nursing calves. Methane measurements were obtained from these "tester" animals in each herd. In 1997, six weanling heifers were added to each herd.

Methane emissions from the three classes of beef cattle were collected on warm-season pastures of bahiagrass and bermudagrass in spring, summer and autumn and ryegrass during January through April.

All pastures were on Memphis silt loam soil. Pasture treatments included:

(1) Control: unimproved pasture with naturalized revegetated cropland. Base forages were warm-season perennials such as bermudagrass and bahiagrass in combination with numerous forbes. Pastures were routinely grazed with continuous stocking during a grazing season with available dry matter (DM) of 500 to 1,000 kg ha^{-1}.

(2) Treatment: well-managed, warm-season perennial pastures of bahiagrass or common bermudagrass, and overseeded with annual ryegrass for use during the appropriate growing season, using best management practices (BMP) with management-intensive grazing (MIG). Each paddock of bahiagrass or bermudagrass was overseeded with ryegrass in September for winter grazing. Phosphorus and potassium were applied in the autumn to maintain a medium soil test level of fertility. The warm-season pastures in BMP received 50 kg N ha^{-1} as ammonium nitrate in split applica-

tions during the growing season. Ryegrass received 40 kg N ha^{-1} as urea in January and again in March.

Twenty-four paddocks of approximately 0.5 ha each in the BMP area were used with MIG with a stocking density of 50 to 60 animal units ha^{-1} d^{-1}. An appropriate recovery time of 15 to 30 days between each grazing period produced 1,000 to 2,000 kg of DM forage ha^{-1}. This stocking density allowed maintenance of forage with at least 500 kg of DM ha^{-1} residue in each grazed paddock.

The unimproved pasture (control) was grazed with continuous stocking throughout the growing season with a herd stocking rate sufficient to maintain at least 500 kg ha^{-1} of available DM forage. Grazing management was established to provide sufficient forage to allow an adequate voluntary intake.

Bahiagrass hay was used as necessary during the winter as a maintenance diet. Hay and various protein supplements were used for the two herds. Protein supplements included: (1) cottonseed meal and corn (CSMC) to make a 14% crude protein (CP) mixture, (2) urea and corn mixture (URC), 14% CP, (3) protein–molasses block (PMB) and (4) limited ryegrass (LRG) grazing when available.

The control herd was managed under conditions similar to those most producers in Louisiana practice. It was maintained on the same pasture at a stocking rate of two cows per hectare. Forage was sometimes limiting when weather was not favorable. Also, this herd was "wintered" with limited supplementation that caused weight loss of about 20% of precalving weight. Ryegrass was available for grazing one or four hours daily.

The BMP pastures were periodically fertilized to maintain a medium level of soil fertility and the animals were managed intensively with periods of stay of one to three days in each paddock to obtain the highest-quality forage available. The warm-season perennial grasses were more tolerant of traffic and the quality difference usually did not justify a paddock shift on a daily basis. Ryegrass, however, being more upright-growing and very high quality, when grazed, had animal rotation with paddock shifts at least daily.

RESULTS AND DISCUSSION

Methane emissions showed considerable variation among different classes of animals, seasons of the year and forages. Daily emissions of 86 to 193 g of CH_4 from heifers and 120 to 255 g CH_4 d^{-1} from cows were within the range of total CH_4 emissions as reported by others using the SF_6 tracer method. The ranges of annual CH_4 if calculated from the ranges of daily emissions reported in this study, would be between 32 and 83 kg per heifer and between 60 and 95 kg per cow. However, the BMP system always had significant effects on the amount of CH_4 that cows emitted with BMP being lower than the continuous grazing. No significant differences were observed in the heifers during spring and summer of 1997 on either bermudagrass or bahiagrass.

A study in 1999 observed that CH_4 production was higher on tropical forage diets than published values for temperate forage diets. This higher methane conversion rate (MCR) of tropical forage species is presumably related to the relatively high levels of fiber and lignin, low levels of nonfiber carbohydrate and low digestibility compared with temperate forage species.

The average body condition scores for cows in both management systems varied between 4 and 7 (on a scale of 1 to 9) when recorded biannually. These scores indicated that cows were generally in acceptable condition.

On bahiagrass, the BMP cows gained weight (ADG) while the control cows lost weight during the September to October (fall 1996) collection. All heifers lost weight. Differences were observed in weight gain between seasons in cows but there were no other significant differences among the treatments for weight gain on bahiagrass. All groups had less DM intake in the fall collection than required to support production above maintenance. The warm-season forages of bahiagrass and bermudagrass in summer and autumn did not support high weight gain or efficient beef production. Forage quality of bahiagrass and in vitro organic matter digestibility usually limits animal performance in the latter part of the summer and into the fall. When forage quality is low, a low stocking density and continuous stocking allow the animals to select portions of the forage plant that are higher in quality. On bahiagrass, the control cows gained slightly more weight in spring and summer than the BMP cows. Continuous stocking allows maximum selective grazing, which frequently results in higher per animal responses than from rotational stocking. This advantage for continuous stocking was observed with both cow and heifer weight changes on bahiagrass or bermudagrass in the July to October 1997 collections.

Daily CH_4 emissions ranged from 120 to 249 g d^{-1} for cows and 86 to 166 g d^{-1} for heifers grazing on bahiagrass. Emissions were lower in the spring when forage quality was higher than in summer and fall with forage quality declining. There was variation between seasons, when CH_4 emissions are expressed per unit of MW, but the BMP grazing management system produced significantly less CH_4 at each collection. The calculated annual rate of CH_4 emission on bahiagrass of 45 to 97 kg for cows and 34 to 61 kg for heifers is well within the range of reported values.

CH_4 emissions on bermudagrass varied between seasons with both cows and heifers emitting less CH_4 in summer of 1997 than in either fall collection. Both cows and heifers emitted less CH_4 on BMP than on continuous bermudagrass pastures. The quality of the forage is also reflected in the production observed on the bermudagrass. Average daily gain was higher in summer than in autumn for both cows and young heifers, and ADG was higher on BMP pasture than on continuous grazing. Both cows and heifers had higher ADG on the bermudagrass BMP pastures. Forage intake is a function of forage quality in that as quality increases, intake also increases.

CH_4 emissions of the growing yearling heifers on ryegrass were significantly different at each collection. One-hour grazing time on ryegrass was adequate as a protein supplement but not sufficient to support the genetic potential production (weight gain) of these heifers. The beef weight gains of the four-hour and ad lib treatments confirmed that high-quality forage can support excellent rates of gain. These stocker heifers gained 1.26 kg daily on ad lib, 0.71 kg daily on four-hour, and only 0.12 kg daily on one-hour grazing of ryegrass. Cool-season annuals can greatly extend the forage grazing season by providing an excellent-quality forage capable of producing gains of 1.0 kg d^{-1}. These weight gains on ryegrass also show increased efficiency of CH_4 emission with increased grazing time. When CH_4 emissions are expressed as CH_4 produced per kg of weight gain, the higher rates of gain are certainly more efficient. Methane emissions per kg of ADG were only 20 to 30 g on ad lib ryegrass that supported 1.1 kg ADG during the spring season. Forage quality as measured by in vitro organic matter digestibility declined from a digestibility in the high 70s in February to the mid 60s in April; CH_4 emission per unit of gain increased for similar amounts of grazing time. With the high-quality ryegrass forage, the additional grazing time was critical to achieve adequate dry matter intake for these stocker animals. The higher weight gain resulted in increased efficiency of beef production with less CH_4 being emitted per unit of gain on ad lib ryegrass. Compared with the one-hour grazing, the ad lib ryegrass produced approximately one-tenth the CH_4 per kg of beef weight gain.

Similar results of CH_4 emissions of 1.51 to 2.34 g of CH_4 per unit of MW were obtained in 1998 as 1997 with the protein supplements fed as wintering diets to the mature cows. Methane emissions on all the protein supplements were significantly greater than observed on the ad lib ryegrass. Differences observed between the protein supplement diets on bahiagrass hay reflected the quality of the hay with greater CH_4 emissions on the lower-digestibility hay. The laboratory analyses of the hay indicated that hay alone was not sufficient for maintenance of these cows.

Protein supplement comparisons were continued in 1998 with the two management levels of feeding with each of the protein supplements. The two management systems were planned to allow the BMP herd to maintain or gain body weight of at least 0.5 kg d^{-1} gain and positive condition scores while the control level of feeding was designed below maintenance to allow a slight weight loss. Early-season limit grazing (one or four hours) of ryegrass (LRG) resulted in less CH_4 emission than other protein supplements. However, during late-season grazing LRG produced the highest CH_4 emissions recorded. With higher forage intakes, more CH_4 was produced. Within each protein supplement, higher feeding levels produced significantly more CH_4.

Development of "environment-friendly" livestock production systems demands that the increased production be met by increased efficiency of production and not through increased animal numbers. Annual CH_4 emissions from the BMP in this study reflect a reduction of 22% when projected with the higher values obtained from the control or continuous grazing system. This figure is a prediction graph using daily CH_4 emission values selected from data of the two management systems represented in this study. By selecting the forage system each month that resulted in the least CH_4 emissions, these mature cows would emit 67.5 kg CH_4 annually vs. 86 kg CH_4 for the continuous grazing and wintering system with the most CH_4 emissions.

Methane emissions are a function of the size of the animal population, quantity of feed consumed and efficiency by which an animal converts feed to product. With a greater amount of CH_4 emitted the efficiency is lower. Improving animal productivity decreases CH_4 emissions per unit of product. At the basic level, feed goes to maintenance and product. Maintenance is the proportion of feed needed to satisfy basic metabolic requirements that keep the animal alive. A significant fraction of the CH_4 emitted by cattle (40–60%) comes from the proportion of feed used for maintenance.

Reproductive efficiency was measured by calving interval, adjusted weaning weights, kg of calf produced per cow exposed, and CH_4 emissions per unit of beef produced. Females in the two management systems were naturally mated from Dec. 15, 1997, through March 15, 1998. Pregnancy rates showed average days pregnant for mature BMP cows were 146.5, as compared with 111.5 days for the control group. The plane of nutrition in the BMP herd was sufficient to support earlier cycling and thus earlier pregnancy and calving dates. This data reflected a 21% advantage in calving interval for the BMP treatment cows. Weaning weights on all calves born in the autumn of 1997 were adjusted according to age of the dam and sex of offspring. The BMP group was 29 kg heavier than the control animals with a 13% advantage in weaning weight efficiency. Total forage was affected by a relatively mild winter and severe spring drought that certainly could have affected pregnancy rates and weaning weights for both groups.

CONCLUSIONS

As ruminants, cattle have a relatively high maintenance requirement associated with rumen fermentation. Therefore, CH_4 emissions for maintenance cannot be modified through management strategies. Emissions of CH_4 beyond those associated with maintenance can be reduced based on level of productivity of the animal. Consequently, implementing proper grazing management practices to improve the quality of pastures increases animal productivity and has a significant effect on reducing CH_4 emission from fermentation in the rumen. Enhancing the level of productivity decreases the maintenance subsidy and thus decreases obligatory CH_4 emissions from fermentation of the feed associated with animal maintenance.

Management-intensive grazing is an effective form of grazing BMP. Advantages may include more uniform grazing, better stand maintenance of some plant species, greater animal production per hectare and increased opportunity for heavy grazing pressures without permanent damage to plants. This management leads to vigorous plant growth, healthy soil and a more constant, nutritious diet for cattle. Overall beef production efficiency increases and as a result the CH_4 emissions per unit of product and total CH_4 emissions into the atmosphere are reduced.

As we gain a better understanding of how grazing management strategies affect livestock responses in a whole-system context, we can increase the efficiency of the forage production system and reduce climate damage. We will also maintain better control of the plant and soil resource while increasing beef production efficiency.

Editor's note: *Content was adapted from the paper "Methane Emissions of Beef Cattle on Forages: Efficiency of Grazing Management Systems," which was published in the Journal Environmental Quality, Vol. 32, January-February 2003, and is courtesy of the authors H. Alan DeRamus, Terry C. Clement, Dean D. Giampola, and Peter C. Dickison.*

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January Self-Study Examination

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1. Of the total U.S. anthropogenic emissions of "greenhouse gas," the methane produced from enteric fermentation by domesticated livestock is estimated to contribute:

[ ] a. 15%.
[ ] b. 21%.
[ ] c. 26%.
[ ] d. 31%.

2. Of the beef cows in the U.S.:

[ ] a. 20% are located in the South.
[ ] b. 30% are located in the South.
[ ] c. 40% are located in the South.
[ ] d. 50% are located in the South.

3. All study pastures were:

[ ] a. loam.
[ ] b. clay loam.
[ ] c. silt loam.
[ ] d. sandy loam.

4. The best management practices (BMP) pastures were periodically fertilized to maintain:

[ ] a. a low level of soil fertility.
[ ] b. a medium level of soil fertility.
[ ] c. a high level of soil fertility.
[ ] d. green forages.

5. Animals on the best management practice pastures were managed with periods of stay of:

[ ] a. 1 to 3 days.
[ ] b. 2 to 4 days.
[ ] c. 3 to 5 days.
[ ] d. 4 to 7 days.

6. For cows, the range of annual methane would be between:

[ ] a. 50 to 85 kg/cow.
[ ] b. 60 to 95 kg/cow.
[ ] c. 70 to 105 kg/cow.
[ ] d. 80 to 115 kg/cow.

7. In the spring when forage quality was higher, emissions were:

[ ] a. at their lowest.
[ ] b. similar to summer emissions.
[ ] c. similar to fall emissions.
[ ] d. at their highest.

8. Compared to continuous bermudagrass pastures, the BMP pastures:

[ ] a. produced less methane emissions for both cows and heifers.
[ ] b. produced less methane emissions for only the cows.
[ ] c. produced less methane emissions for only the heifers.
[ ] d. produced higher methane emissions for both cows and heifers.

Over

9. Annual methane emissions from the BMP in this study reflect a reduction of:

[ ] a. 15%.
[ ] b. 18%.
[ ] c. 22%.
[ ] d. 25%.

10. A significant fraction of the methane emitted by cattle comes from the proportion of feed used for maintenance, approximately:

[ ] a. 10 – 30%.
[ ] b. 20 – 40%.
[ ] c. 30 – 50%.
[ ] d. 40 – 60%.

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