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Quantitative results for methane production of cattle in Germany

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Abstract

An extensive number of investigations on the energetic utilization efficiency of nutrients and feedstuffs by cattle were carried out in the former Oskar-Kellner-Institute (now the »Oskar Kellner« Research Unit of Nutritional Physiology at the Research Institute for the Biology of Farm Animals (FBN), Dummerstorf). The amounts of methane (CH_4) that they produced were compiled and stratified with regard to various performances, dietary nutrient composition and nutrition levels. With increasing food intake and performance, an increase of CH_4 emission per animal was observed. However, with increasing performance, a strong decrease of CH_4 production per unit of product was determined. Altogether, the 12.74 million cattle in Germany produce 1.04 million tons of CH_4 per year. This represents 1.25 % of the CH_4 production of the 1.3 thousand million (UK)/billion (US) cattle in the world or 0.22 % of the total emission on the earth. As a greenhouse gas, CH_4 from cattle worldwide and from cattle in Germany account for 3.5 % and 0.04 % of global warming, respectively. In addition, opportunities for a further reduction of enteric CH_4 release are discussed.

Keywords: CH_4 production, cattle, food intake, performance level

Zusammenfassung

Ergebnisse zur quantitativen Methan-Produktion der Rinder in Deutschland

Im Rahmen der Untersuchungen zur energetischen Verwertung der Nährstoffe und Futtermittel im früheren Oskar-Kellner-Institut (jetzt Forschungsbereich Ernährungsphysiologie »Oskar Kellner« des Forschungsinstituts für die Biologie landwirtschaftlicher Nutztiere (FBN), Dummerstorf) erfolgten auch umfangreiche Messungen zur Methan(CH_4)-Produktion von Rindern bei verschiedenen Leistungen und unterschiedlicher Ernährung. Auf der Basis dieser Daten wurde unter Nutzung der ermittelten Zusammenhänge zwischen Nährstoffzusammensetzung des Futters bzw. Höhe der Futteraufnahme und CH_4-Bildung die CH_4-Emission von Rindern in Deutschland berechnet. Nach der Einzeldarstellung des CH_4-Ausstoßes für Milch- und Mutterkühe, Kälber und Jungrinder, weibliche Zucht- und Nutztiere sowie Jungmastbullen wird eine Gesamtbilanz gezogen. Danach produzieren die 12,74 Millionen Rinder in Deutschland 1,04 Millionen t CH_4 pro Jahr. Das sind 1,25 % der von den weltweit 1,3 Milliarden Rindern produzierten CH_4-Menge oder 0,22 % der Gesamtemission auf der Erde. Als Treibhausgas macht die von den Rindern weltweit bzw. in Deutschland produzierte CH_4-Menge einen Anteil an der

Erderwärmung von 3,5% bzw. 0,04% aus. Zusammenfassend werden Möglichkeiten für künftige Reduzierungn des enterischen CH_4-Ausstoßes diskutiert.

Schlüsselwörter: CH_4-Produktion, Rind, Futteraufnahme, Leistungsniveau

Introduction

Mitigation of methane (CH_4) production by ruminants, and in particular cattle, has become a subject of public discussion and an important area of research because accumulation of this greenhouse gas contributes to global warming. (PELCHEN *et al.* 1998, SEELAND and MARTIN 1998). Exact and reproducible determinations of CH_4 emissions form the basis for decreasing the uncertainty in greenhouse gas emission inventories and for the development of viable reduction strategies. Of note, exact measurements of enteric CH_4 production have been carried out worldwide in only a few institutions because of the large technical effort that these entail. One of these facilities is the Oskar Kellner Institute, founded by NEHRING, which is now a research unit at the Research Institute for the Biology of Farm Animals (FBN) in Dummerstorf (Germany). Using respiration chambers, large data sets have been created including CO_2 production (JENTSCH *et al.* 2009) and CH_4 production over a time period of 32 years (JENTSCH *et al.* 2000 and 2001).

Here, information obtained from these studies and data from more recent publications by JENTSCH *et al.* (2007) and VERMOREL *et al.* (2008) are used to calculate reasonable quantitative values for CH_4 emissions from cattle in Germany.

Material and methods

For the evaluation, data from 337 respiration experiments each with 3-12 animals of various categories (oxen, young bulls, lactating and non-lactating cows, heifers) were used. The measurements were made in respiration chambers between 1957 to 1989 within the scope of investigations on energetic feed evaluation and energy requirement of farm animals (JENTSCH *et al.* 2000, 2001, 2003). Using CH_4 release data from these studies, regression equations were formed allowing calculation of CH_4 formation from the level of feed intake or the nutrient composition of the diet (JENTSCH *et al.* 2007).

By means of the following equation, CH_4 production can be predicted on the basis of the content of digestible nutrients in the diet.

$$m = 1.32x_1 - 0.56x_2 + 1.68x_3 + 2.78x_4 \qquad r^2 = 0.858 \qquad (1)$$

where is m the CH_4 energy (kJ), x_1 the digestible crude protein (g), x_2 the digestible crude fat (g), x_3 the digestible starch and sugar (g), x_4 the digestible N-free residues (g) (that is the digestible fraction of plant cell wall substances).

Thus, for example, 1.32 kJ CH_4 is formed per 1 g of digestible crude protein, with nutritional fats exerting a negative influence on CH_4 formation and N-free residues accounting for the highest value at 2.78 kJ per g.

A calculation based on the relation between dry matter intake (DMI) per kg live weight and daily CH_4 release leads to comparable results:

$$y = 1802 - 21.1x \qquad r^2 = 0.224 \qquad (2)$$

where is *y* the CH_4 energy (kJ), *x* the DMI (g feed/kg BW).
For the estimations presented, the daily CH_4 production per animal was calculated using equation 2. The daily feed intake was adjusted to body weight and performance according to data published by PIATKOWSKI *et al.* (1990). The following conversion factors given by BROUWER (1965) and HOFFMANN and SCHIEMANN (1980) have been used to convert CH_4 energy (kJ) to CH_4 values in mass units (g, kg): 0.716 g/l; 39.57 kJ/l; 1g = 55 kJ.

VERMOREL *et al.* (2008) used data from feeding trials to calculate the quantity of released CH_4 based on equations from the literature estimating the digestible and metabolizable energy of the rations. Their results are compared with the data presented here.

Results and discussion

The DMI of dairy cows has been calculated for individual performance levels, for the dry period and for the maintenance energy requirement according to PIATKOWSKI *et al.* (1990). Thereafter, DMI increases with increasing annual milk yield from 22.3 (4 000 kg of milk) to 31.5 g/kg body weight (10 000 kg of milk) (Table 1).

Table 1
DMI per cow (650 kg BW) with respect to milk yield
Futterverzehr in Trockenmasse (DMI) je Kuh mit 650 kg Lebendmasse (BW) in Abhängigkeit von der Milchleistung

Milk yield, energy corrected (ECM)		DMI	
kg/a	kg/d	kg/d	g/kg BW
4 000	14	14.5	22.3
6 000	20	16.5	25.4
8 000	26	18.5	28.5
10 000	32	20.6	31.5
Dry period (60 d)		10.0	15.4
Maintenance		7.0	10.8

As shown in table 2, the calculated CH_4 emission per cow increases according to the performance levels from 351 g/d at 4 000 kg milk to 424 g/d at 10 000 kg. According to equation (1), this surprisingly small elevation can be attributed to the high proportion of starch in the concentrate. This is also confirmed by the responses to low-concentrate rations fed during the dry period and at maintenance conditions (Table 2).

Table 2
CH_4 production per cow (650 kg BW) with respect to milk yield
CH_4-Produktion der Kuh (650 kg BW) in Abhängigkeit von der Leistung

Milk yield, ECM	CH_4 release					
kg/a	g/kg DM	g/d	kg/305 d	Dry period	kg/a	g/kg milk
4 000	24.22	351	107.0	16.1	123.1	30.8
6 000	23.04	380	115.9	16.1	132.0	22.0
8 000	21.84	404	123.2	16.1	139.3	17.4
10 000	20.70	424	129.4	16.1	145.5	14.6
Dry period (60 d)	26.87	269		16.1		–
Maintenance	28.29	198			72.3	–

Therefore, the annual CH_4 emissions per cow range from 123.1 kg at 4 000 kg milk to 145.5 kg at 10 000 kg milk. However, the release of CH_4 per kg of milk decreases by more than a half from 30.8 to 14.6 g. This leads, in turn, to a significant reduction of CH_4 emissions in high yielding cows. This reduction is due to the fact that, for example, 50 cows with 8 000 kg milk produce the same amount of milk as 100 cows with 4 000 kg per year, but there will be no CH_4 production derived from the maintenance needs for half of the cows.

With an average milk yield of 6 849 kg (Arbeitsgemeinschaft Deutscher Rinderzüchter [ADR] 2008) per cow and year, 135 kg of CH_4 are emitted. The corresponding annual CH_4 emission of the 4 087 million dairy cows then amounts to 551 745 tons.

Under French production conditions VERMOREL *et al.* (2008) have calculated a mean annual CH_4 production of 117.7 kg per cow with a milk yield of 6 300 kg/a ranging from 90-164 kg. Thus, despite the different methodological approaches our calculated mean annual CH_4 production value agrees well, considering the performance differences.

In addition to dairy cows, another category of »other cows« that are not milked and are kept as suckler cows should be considered. Their milk is used directly by the calf and amounts to 2 000 kg per year. Assuming an average body weight of 650 kg and a daily feed consumption of 15.4 g/kg body weight, the annual CH_4 production of these cows amounted to 98 kg.

The equation used for dairy cows to calculate the daily CH_4 production is also valid for growing cattle.

Table 3
DMI and CH_4 release of heifers showing a daily weight gain of 600 g
Futteraufnahme und CH_4-Produktion weiblicher Jungrinder bei 600 g täglicher Lebendmassezunahme

BW range	DMI		CH_4 release		
kg	kg/d	g/kg BW	g/kg DM	g/d	kg/a
200-300	5.8	23	25.7	149	54.4
300-400	7.4	21	24.7	183	66.8

Hence, for the range of 200 to 400 kg body weight, 60.6 kg CH_4 per animal are produced. The CH_4 release values for young fattening bulls as given in Table 4 were calculated with the same approach.

Table 4
DMI and CH_4 release by young male beef cattle with a daily weight gain of 1 000 g
Futteraufnahme und CH_4-Produktion von Jungmastbullen bei 1 000 g täglicher Lebendmassezunahme

BW range	DMI		CH_4 release		
kg	kg/d	g/kg BW	g/kg DM	g/d	kg/a
250-350	6.3	23	25.7	162	59.1
350-450	8.0	20	25.0	200	73.0
450-550	8.5	17	25.9	220	80.3

In young fattening bulls, the annual CH_4 emission was estimated to be 70.8 kg. VERMOREL *et al.* (2008) have reported values of 45.5 kg of CH_4 for heifers and 49.4 kg for young fattening cattle of both sexes. Thus, the differences between French and German results in young animals are greater than for cows. This may be partly attributable to the lower body weight gain and the higher age of calving of up to 30 months in Germany and the use of heifers for fattening.

For calves of less than 12 months of age, a body weight of 200 kg and a feed intake of 4.5 kg had been assumed. Based on these data, CH_4 production values of 24.2 g per kg DMI, of 109 g per day and of 39.8 kg per year were calculated.

For breeding bulls with a daily DMI of 9 kg CH_4 release per kg DM, per day and per year was estimated to be 28.9 g, 260 g and 95 kg, respectively.

The CH_4 production of all cattle in Germany (ADR 2008) can be differentiated by the various animal categories and is given in Table 5.

Table 5
Balance of CH_4 emission of the various categories of cattle in Germany
Bilanz der CH_4-Emission der einzelnen Kategorien des Rinderbestandes in Deutschland

Category	Number (in 1 000)	CH_4 release per year	
		kg/animal	tons in total
Dairy cows	4 087	135.0	551 745
Suckler cows	669	98.0	65 562
Calves and young cattle <12 months	3 976	39.8	158 245
Female breeding and farm animals, 12-24 months	1 714	60.6	103 868
Heifers, breeding and farm animals	781	60.6	47 329
Cattle, female and male for slaughter >12 months	1 422	70.8	100 678
Cows for slaughtering	88	90.0	7 920
Total	12 737		1 035 347

Thus, the 12 737 000 head of cattle kept in Germany in 2007 produced per year 1 035 347 tons of CH_4, of which 60 % can be attributed to dairy and suckler cows.

In conclusion the CH_4 emissions of cattle kept in Germany represent about 1 million tons per year and have to be seen in the context of the global CH_4 output into the atmosphere which amounts to an estimated 400-450 million tons. Main sources are the lowland marshes and wetlands, the burning of forests and grasslands, the strongly increasing numbers of termites in the harvested tropical forests, rice fields, coal mines, landfills, the oceans and finally the approximately 1.3 thousand million (UK)/billion (US) cattle worldwide. Their share has been calculated at 80-90 million tons, accounting for about one fifth of the total emissions. Thus, the cattle in Germany emit 1.25 % of the global CH_4 produced by cattle or 0.22 % of the total emissions, including the above-mentioned sources, such as lowland marshes. Based on our current state of knowledge, the total annual release of CH_4 as a greenhouse gas provides a share of 18.6 % to global warming. The share of the global cattle population of 1.3 thousand million (UK)/billion (US) is thus one fifth, i.e. 3.5 %, and the CH_4 emissions of cattle in Germany amount to 0.04 %.

A high proportion of agricultural greenhouse-gas emissions are generated by dairy cattle enteric CH_4 production. This contribution can be reduced primarily by increasing the performance and thus, the milk yield per animal. A further important economic effect should also be considered: 50 cows producing 8 000 kg of milk per year have the same milk output as 100 dairy cows with an annual performance of 4 000 kg milk. Thus, the CH_4 emitted for the maintenance requirements of the smaller number of cows shows a reduction and, at the same time, the number of sheds and working expenses for milking decline.

The CH_4 released by cattle is produced by ruminal methanogens during the microbial digestion of nonstarch polysaccharides (e.g. cellulose). This unique and valuable capacity of ruminants allows utilizing substrates indigestible to pigs, poultry and man, thereby lessen the competition for food resources. Therefore, it is not justified to assess cattle industry by its contribution to global warming only. Rather, in a comprehensive assessment with regard to global food security in terms of quantity and quality it is necessary to include fully all available food energy sources such as also the nonstarch biomass.

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