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Estimation of the Methane Emission Factor for Buffalo Cattle and Bulls

Research Article

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ABSTRACT

In order to determine the incidence of buffaloes on enteric CH_4 emissions, information about animal production and farm management was analyzed and the CH_4 emission factor estimated using the IPCC Tier 2 model. CH_4 emission factor for the category of buffalo cattle and buffalo bulls was estimated for the period 2000-2007, in Italy, Europe and worldwide. During 2007, the CH_4 emission factor for buffalo cattle and bulls worldwide was 61.35 and 47.48 kg CH_4/head/yr respectively. The CH_4 emission factor from 2000 to 2007 worldwide showed an increase of 1.94 and 4.68 kg CH_4/head/yr for buffalo cattle and bulls respectively, also considering that the buffalo population is increasing and that the CH_4 emission factor depends on body weight and milk yield.

KEY WORDS buffalo cattle and bulls, CH_4 emission factor.

INTRODUCTION

Methane is a greenhouse gas (GHG) that remains in the atmosphere for approximately 9-15 years. It is over 20 times more effective at trapping heat in the atmosphere than carbon dioxide over a 100-year period and it is emitted from a variety of natural and anthropogenic sources such as landfills, natural gas and petroleum systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial processes. Ruminant livestock are the single most important source of CH_4 emissions.

Buffaloes typically lose 6% of their ingested energy as eructated methane (Johnson and Johnson, 1995). This process begins approximately four weeks after birth when solid feeds are retained in the reticulorumen. Fermentation and methane production rates rise then rapidly during reticulorumen development. Generally, as diet digestibility increases, variability in methane loss also increases. There are two primary mechanisms causing this variation in methane production. The first is the amount of dietary carbohydrate fermented in the reticulorumen. This mechanism is heavily influenced by the diet-animal interaction, because it acts on the equilibrium between the carbohydrates' ruminal rate of fermentation and their transit.

The ratio of different volatile fat acids produced during the ruminal fermentations can also influence the methane production. The most important volatile fat acid for this production is propionic acid, as it can influence both ruminal pH and the equilibrium in the ruminal bacterial population. The ratio between acetic and propionic acid depends on the fiber quantity ingested with the diet, and the highest will be this ratio, the larger will methane production result.

Several equations can assist in the methane prediction, that take into account the assumption of dry matter, the quality and quantity of carbohydrates given by diet, the digestibility of the food fiber, the weight of the animal and their productive aspects. Recently some studies has developed comprehensive guidelines for national greenhouse gas and for livestock CH_4, suggesting different levels (Tiers 1, 2 and 3) of CH_4 estimation. Tiers 1 is a simplified initial estimation method and is recommended when enteric fermentation is a not a “key category” and the animal species is not significant in the country, whereas Tiers 2 and 3 are more advanced approaches requiring country-specific data and more detailed characterization of livestock population and farming situations. Tiers 3 applies when a country-specific methodology for enteric CH_4 emission estimation has been developed. As recommended by the some studies, Tier 2 was chosen to estimate the enteric CH_4 emission factor for buffalo cattle and bulls.

The increasing economic importance of the Italian buffalo stems from the absence of production quotas in the European Union and especially from the high market demand for mozzarella cheese made from buffalo milk, resulting in more than double the price of cattle milk, and also from the new market demand for buffalo meat. Animals are usually kept in paddocks, and feeding is mainly based on *unifeed* during lactation, and on pasture for dry cattle and young animals. The Italian buffalo cow produces on average 2150 kg of milk per lactation (the length of lactation is set at 270 days), with a content of 8.28% and 4.74% in fat and protein respectively (AIA, 2006).

According to FAO, the Italian buffalo population has increased from 182000 head in 2000 (68% female) to 231000 head in 2007 (63% female). However, in this species there is limited knowledge about the enteric CH_4 emission factor.

The aim of this study was therefore to contribute to the national greenhouse gas emission inventory, estimating the enteric methane emission factor in Italian Mediterranean buffalo dairy cattle and bulls.

In this study the annual statistical reports on buffalo populations published by the FAOSTAT were the main source of information used for the enteric CH_4 emission factor.

MATERIALS AND METHODS

For this study, the period 2000-2007 was chosen, and buffaloes were divided into two categories, male and female. The enteric CH_4 emission factor depends on the gross energy intake (GEI) obtained from feed; the GEI, in turn, is the amount of energy consumed by an animal in order to satisfy maintenance, activity, production and metabolic requirements. Each parameter was calculated according to the following equations:

Net energy required by the animal for maintenance (MJ/d)

$NE = Cfi \times (weight)^{0.75}$

Where:
Weight: animal live weight, in kg.
Cfi: a coefficient varying according to animal category (0.322 for non-lactating buffalo and 0.335 for lactating buffalo).

Net energy for growth (MJ/d)

$NEg = 4.18 \times \{0.0635 \times [0.891 \times (BW \times 0.96) \times (478/(C \times MW)]^{0.75} \times (WG \times 0.92) \times 1.097\}$

Where:
BW: body weight (BW) of the animal, in kg.
C: a coefficient of 0.8 for females, 1.0 for castrates and 1.2 for bulls (NRC, 1994).
MW: the mature body weight of an adult animal, kg.
WG: the daily weight gain, kg/d.

Net energy mobilized (MJ/d)

$NE_m = NEg \times (-0.8)$

Net energy for lactation (MJ/d)

$NE_l =$ kg of milk per day $\times (1.47+0.40 \times Fat)$

Net energy for work (MJ/d)

$NEw = 0.10 \times NE_m \times$ hours of work

Where:
Hours of work: per day in buffalo was equal to 0.

Net energy for pregnancy (MJ/d)

$NE_p = C_{pregnancy} \times NE_m$

Where:
$\mathbf{C}_{pregnancy}$: pregnancy coefficient= 0.10.

Ratio of net energy available in a diet for maintenance to digestible energy consumed= REM

$REM = 1.123 - (4.092 \times 10^{-3} \times DE) + [1.126 \times 10^{-5} \times (DE)\ 2] - (25.4/DE)$

Where:
DE: digestible energy expressed as a percentage of gross energy.

Ratio of net energy available for growth in a diet to digestible energy consumed= REG

$REG = 1.164 - ((5.160 \times 10^{-3} \times DE) + (1.308 \times 10^{-5} \times DE)) - (37.4/DE)$

According to the some studies the equation to estimate the GEI is the following:

Gross energy for buffalo

GEI= $\{(NE_m+NE_a+NE_l+NE_w+NE_p) / REM + (NE_g/REG)\} / (DE/100)$

The emission factor for each animal category should be calculated using the following equation:

Emission factor, kg CH_4/head/yr

EF= (GEI×Ym×365 d/yr) / (55.65 MJ/kg CH_4)

Where:
EF: emission factor, kg CH_4/head/yr.
GEI: gross energy intake, MJ/head/d.
Ym: methane conversion rate, namely the fraction of gross energy contained in feed converted to methane. The Ym value is 6% in buffalo cattle and bulls.

Table 1 the chemical characteristics of the diet in object are reported.

RESULTS AND DISCUSSION

It is a far from resolved matter that the assumed increase in meat production and animal productivity can be indefinitely sustained. For example, Capper *et al.* (2008) argue that livestock production cannot be greatly increased because nearly all of the world's suitable rangelands are already intensively exploited.

They claim that the rapidly growing demand for meat and dairy products can only be met by livestock production in feedlots, what would result in a rising demand for feed, requiring further development of agricultural land and further GHG emissions.

Following this consideration, the GEI (MJ/head/d) and CH_4 emission factor (kg CH_4/head/d) are respectively reported in tables 1 and 2 for buffalo cattle and bulls. The EF is calculated taking also into account that 6% of GE intake is lost to CH_4 energy.

Table 1 shows that in Europe the buffalo cow population represents 0.21% of the world population, while in Italy buffalo cattle make up 0.11% of global population.

In 2005 milk production in Europe accounted for 0.82% of the entire production worldwide; although the following year the incidence was much lower (0.18%).

Italy recorded an average 0.25% of the world production in 2005. The impact on the CH_4 emission factor is more interesting: in Europe, and especially in Italy, it is always higher than in the rest of the world. The CH_4 emission factor was found higher than those reported by Còndor *et al.* (2008).

Tables 2 shows that the quantity of buffalo meat production in Europe and Italy is significantly lower than its worldwide counterpart. This ratio does not match the level of the CH_4 emission factor. In both cases, CH_4 is always higher per livestock unit than the world production.

Table 1 Population, production characteristics, GE intake and CH_4 emission factor in buffalo cattle

Year	Country	Population (heads)	Milk production (tonnes)	GEI ($MJ \times head^{-1} \times yr^{-1}$)	CH_4 emission factor ($kg\ CH_4 \times head^{-1} \times yr^{-1}$)
2000	Europe	232499	176700	157.56	62.00
2000	Italy	123760	135100	170.86	67.24
2000	World	111658328	66500380	150.97	59.41
2001	Europe	234880	124600	148.36	58.38
2001	Italy	123760	153461	176.81	69.58
2001	World	113126254	69267265	151.64	59.67
2002	Europe	244726	214600	162.25	63.85
2002	Italy	131766	147260	171.90	67.65
2002	World	114776643	70859326	151.84	59.75
2003	Europe	238762	159700	153.91	60.57
2003	Italy	125800	171870	181.87	71.57
2003	World	116743644	73503775	152.33	59.95
2004	Europe	279706	339300	175.73	69.15
2004	Italy	151907	183881	175.62	69.11
2004	World	117402713	76097687	153.08	60.24
2005	Europe	266096	645800	224.40	88.31
2005	Italy	142800	215228	187.52	73.80
2005	World	118678350	78889010	153.74	60.50
2006	Europe	242667	147600	151.48	59.61
2006	Italy	139400	221069	190.68	75.04
2006	World	119808676	82189954	154.59	60.84
2007	Europe	270053	425000	190.19	74.85
2007	Italy	157080	200000	178.14	70.10
2007	World	120528598	86574529	155.89	61.35

Table 2 Population, production characteristics, GE intake and CH_4 emission factor in buffalo bulls

Year	Country	Population (heads)	Milk production (tonnes)	GEI ($MJ \times head^{-1} \times yr^{-1}$)	CH_4 emission factor ($kg\ CH_4 \times head^{-1} \times yr^{-1}$)
2000	Europe	102300	1767	274.35	53.98
2000	Italy	58240	1467	272.20	53.56
2000	World	50254509	2996324	217.54	42.80
2001	Europe	103347	1246	270.61	53.25
2001	Italy	58240	1046	269.17	52.96
2001	World	53235884	2953280	215.01	42.31
2002	Europe	107679	2146	277.08	54.52
2002	Italy	62008	1991	275.96	54.30
2002	World	54012538	3018529	219.70	43.23
2003	Europe	105055	1567	272.91	53.70
2003	Italy	59200	1352	271.37	53.40
2003	World	54938185	3010601	219.13	43.12
2004	Europe	123071	3393	286.05	56.28
2004	Italy	71485	3175	284.48	55.98
2004	World	55248336	3112609	226.47	44.56
2005	Europe	117082	6458	308.09	60.62
2005	Italy	67200	6090	305.44	60.10
2005	World	55848635	3171730	230.72	45.40
2006	Europe	106777	1476	272.26	53.57
2006	Italy	65600	1085	269.45	53.02
2006	World	56380554	3253652	236.61	46.56
2007	Europe	118823	4250	292.21	57.50
2007	Italy	73920	4060	290.84	57.23
2007	World	56719340	3322166	241.32	47.48

These trends may well be justified by farm management characteristics, as there are more intensive systems of farming in Europe and particularly in Italy, compared to the rest of the world, where livestock systems are more extensive. These results are in agreement with the above study by Capper *et al.* (2008). The values reported in Table 2 were lower than those reported by Còndor *et al.* (2008); in Italy, average milk yield per buffalo cow in 1990 was 1893 kg, compared to 2211 kg in 2008. Although the energy requirement for maintenance is the most important factor to estimate the CH_4 emission factor, as shown in Figure 1 this required energy is not influenced by production, while the daily energy requirement rises according to the amount of milk produced.

Hence the fraction of energy required for maintenance is also reduced. Consequently, it appears clear that farm management strongly influences the amount of produced CH_4. The total energy requirement per kg of produced milk is therefore reduced: a buffalo cow producing 10 kg/d requires 11.3 MJ/kg of milk, whereas a buffalo cow yielding 30 kg/d needs only 4.19 MJ/kg of milk (Figure 1). Similar results were found by Capper *et al.* (2009) in a study conducted on cattle. As summarized by the some studies, emission factors vary greatly according to the production address of cow, their feed regime and their productivity. However, best-practice farm management has reduced GHG emissions according to Còndor *et al.* (2008) on a study on dairy cattle (Figure 2).

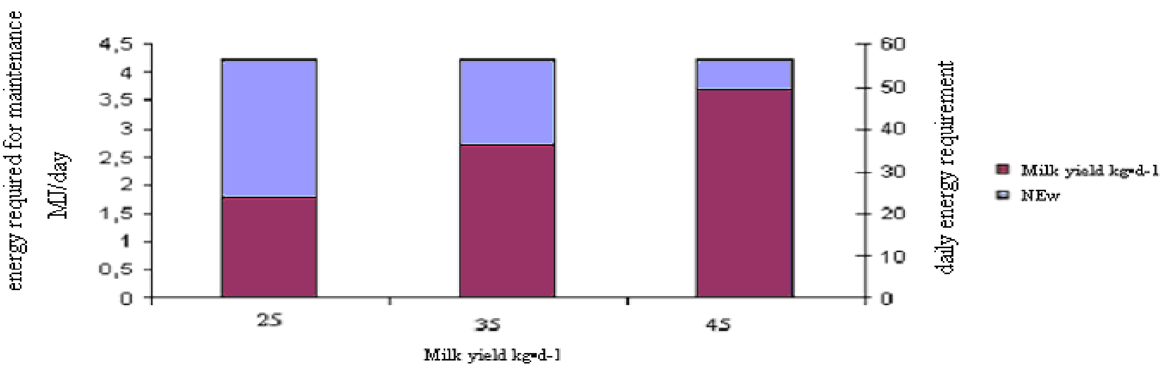

Figure 1 Relationship between energy maintenance and milk production in Italian buffaloes

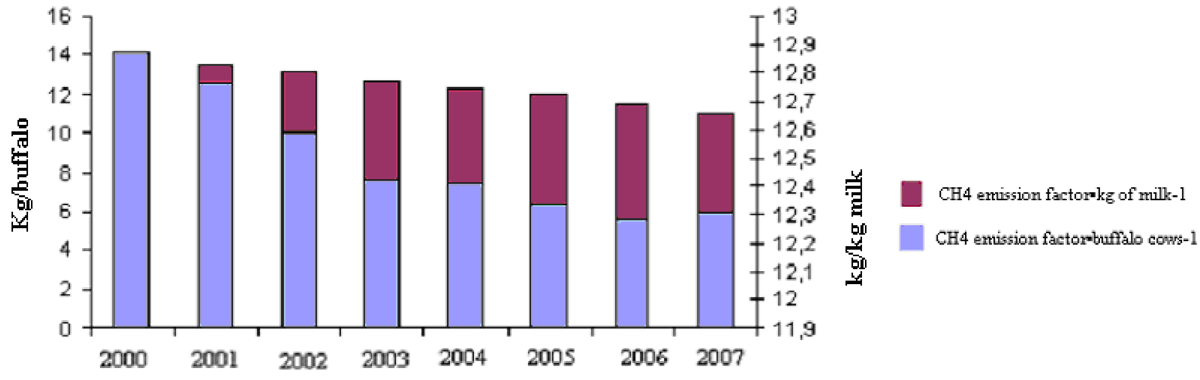

Figure 2 CH_4 emission factor per buffalo cattle and per Kg of milk since 2000 to 2007 in the world

Holther *et al*. (1992) reported that the enteric CH_4 emission factor was 7.5% of GEI for dairy cattle; these authors found a value of 39.35% in buffalo, in agreement with findings reported by Còndor *et al*. (2008).

CONCLUSION

Since little is known about CH_4 enteric emissions in buffalo, this work was set to advance the knowledge of the influence of this livestock species on the enteric CH_4 emission factor. According to the Tier 2 approach under guidelines, an emission factor of 70.10 kg CH_4/head/yr for buffalo cattle in Italy, of 74.85 kg CH_4/head/yr in Europe and of 61.35 kg CH_4/head/d worldwide was estimated for the years 2007. For buffalo bulls, the CH_4 emission factor was estimated to be 57.23 kg CH_4/head/d in Italy, 57.50 kg CH_4/head/d in Europe and of 47.48 kg CH_4/head/d in the world. Further in-depth research is needed to enhance our knowledge of the possible factors influencing this parameter in order to achieve maximum compliance with environmental quality and standards of animal welfare.

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