Estimation of the Methane Emission Factor for Buffalo Cattle and Bulls

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ABSTRACT

In order to determine the incidence of buffaloes on enteric CH4 emissions, information about animal production and farm management was analyzed and the CH4 emission factor estimated using the IPCC Tier 2 model. CH4 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 CH4 emission factor for buffalo cattle and bulls worldwide was 61.35 and 47.48 kg CH4/head/yr respectively. The CH4 emission factor from 2000 to 2007 worldwide showed an increase of 1.94 and 4.68 kg CH4/head/yr for buffalo cattle and bulls respectively, also considering that the buffalo population is increasing and that the CH4 emission factor depends on body weight and milk yield.

KEY WORDS buffalo cattle and bulls, CH4 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 CH4 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 CH4, suggesting different levels (Tiers 1, 2 and 3) of CH4 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 CH4 emission estimation has been developed. As recommended by the some studies, Tier 2 was chosen to estimate the enteric CH4 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 CH4 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 CH4 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 CH4 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)**

\[
NE = C_{fi} \times \text{weight}^{0.75}
\]

Where:
- Weight: animal live weight, in kg.
- C_{fi}: 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)**

\[
NE_{g} = 4.18 \times \left[ 0.0635 \times 0.891 \times (BW \times 0.96)^{0.75} \times (WG \times 0.92) \times 1.097 \right]
\]

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)**

\[
NE_m = NE_g \times (-0.8)
\]

**Net energy for lactation (MJ/d)**

\[
NE_l = \text{kg of milk per day} \times (1.47 + 0.40 \times \text{Fat})
\]

**Net energy for work (MJ/d)**

\[
NE_w = 0.10 \times NE_m \times \text{hours of work}
\]

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:
- C_{pregnancy}: pregnancy coefficient= 0.10.

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

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

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**

\[
REG = 1.164 - (5.160 \times 10^{-3} \times \text{DE}) + (1.308 \times 10^{-5} \times \text{DE})
\]

Where:
- \text{DE}: digestible energy expressed as a percentage of gross energy.
According to some studies, the equation to estimate the GEI is the following:

**Gross energy for buffalo**

\[
\text{GEI} = \left\{ \text{NE}_m + \text{NE}_a + \text{NE}_l + \text{NE}_w + \frac{\text{NE}_p}{\text{REG}} \right\} / (\text{DE}/100)
\]

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

**Emission factor, kg CH}_4/\text{head/yr}**

\[
\text{EF} = \left( \frac{\text{GEI} \times \text{Ym} \times 365 \text{ d/yr}}{55.65 \text{ MJ/kg CH}_4} \right)
\]

Where:
- **EF**: emission factor, kg CH}_4/\text{head/yr}.
- **GEI**: gross energy intake, MJ/\text{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 shows 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\textsubscript{4} emission factor (kg CH\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{4} emission factor was found higher than those reported by Côndor *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\textsubscript{4} emission factor. In both cases, CH\textsubscript{4} is always higher per livestock unit than the world production.
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 CH₄ 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 CH₄. 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](https://www.SID.ir)

**Table 2** Population, production characteristics, GE intake and CH₄ emission factor in buffalo bulls

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Population (heads)</th>
<th>Milk production (tonnes)</th>
<th>GEI (MJ×head⁻¹×yr⁻¹)</th>
<th>CH₄ emission factor (kg CH₄×head⁻¹×yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Europe</td>
<td>102300</td>
<td>1767</td>
<td>274.35</td>
<td>53.98</td>
</tr>
<tr>
<td>2000</td>
<td>Italy</td>
<td>58240</td>
<td>1467</td>
<td>272.20</td>
<td>53.56</td>
</tr>
<tr>
<td>2000</td>
<td>World</td>
<td>50254509</td>
<td>2996324</td>
<td>217.54</td>
<td>42.80</td>
</tr>
<tr>
<td>2001</td>
<td>Europe</td>
<td>103347</td>
<td>1246</td>
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</tr>
<tr>
<td>2001</td>
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<tr>
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<td>2953280</td>
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<td>2146</td>
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<tr>
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<td>1991</td>
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<tr>
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<tr>
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<tr>
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<tr>
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<td>56719340</td>
<td>3322166</td>
<td>241.32</td>
<td>47.48</td>
</tr>
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</table>

**Figure 1** Relationship between energy maintenance and milk production in Italian buffaloes
Holther et al. (1992) reported that the enteric CH₄ 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 Cóndor et al. (2008).

CONCLUSION

Since little is known about CH₄ enteric emissions in buffalo, this work was set to advance the knowledge of the influence of this livestock species on the enteric CH₄ emission factor. According to the Tier 2 approach under guidelines, an emission factor of 70.10 kg CH₄/head/yr for buffalo cattle in Italy, of 74.85 kg CH₄/head/yr in Europe and of 61.35 kg CH₄/head/d worldwide was estimated for the years 2007. For buffalo bulls, the CH₄ emission factor was estimated to be 57.23 kg CH₄/head/d in Italy, 57.50 kg CH₄/head/d in Europe and of 47.48 kg CH₄/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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