Agriculture, Ecosystems and Environment 195 (2014) 202–210

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Methane emission inventories for enteric fermentation and manure management of yak, buffalo and dairy and beef cattle in China from 1988 to 2009

B. Xue [a], L.Z. Wang [a], T. Yan [b,*]

[a] Animal Nutrition Institute, Sichuan Agricultural University, Ya'an, Sichuan 625014, China
[b] Agri-Food and Biosciences Institute, Hillsborough, Co. Down BT26 6DR, United Kingdom

ARTICLE INFO

Article history:
Received 18 September 2013
Received in revised form 6 June 2014
Accepted 8 June 2014
Available online 26 June 2014

Keywords:
China
Large ruminant
Methane inventory
Tier 1
Tier 2

ABSTRACT

Large ruminant production systems (dairy, beef, buffaloes and yaks) in China have experienced significant changes during the last 30 years driven by increased demand for milk and meat consumption and discontinued use of beef cattle and buffaloes as draft animals. The present study aimed to evaluate the effects of these changes on methane (CH_4) emissions from enteric fermentation and manure management in large ruminants in China. The emissions were developed using Tier 1 and 2 methodologies of the International Panel on Climate Change. The Tier 2CH_4 emission for each species was a sum of emissions calculated from several groups based on their physiological states, e.g. milking cows, dry cows, sires and steers/heifers at various ages. Total CH_4 emission inventory for dairy cattle, beef cattle, buffaloes and yaks in China increased gradually from 5530 to 6761 Gg/year or 4514 to 5777 Gg/year calculated using the Tier 1 or 2 method during the period of 1988–2009. This increase was driven by increased population and production of dairy and beef cattle (e.g. Tier 2CH_4 emissions increased respectively from 125 to 1028 Gg/year and from 2915 to 3689 Gg/year). However, during the same period Tier 2CH_4 emissions from buffaloes and yaks reduced from 860 to 593 Gg/year and 614 to 467 Gg/year, respectively. Beef cattle were main emitters which produced 63.8% of total emissions in 2009, followed by dairy cattle (17.8%), buffaloes (10.3%) and yaks (8.1%). There was a large difference in provincial contributions. In 2007, the 3 highest emission provinces (Sichuan, Tibet and Henan) each contributed 8.5–10.5% to national emissions, and the lowest 3 accounted for only 0.1–0.2% (Beijing, Zhejiang and Shanghai). The uncertainties associated with these inventories were discussed. These results provide benchmark information for Chinese authorities to develop appropriate policies and mitigation strategies to reduce carbon footprint in the large ruminant production sector in China.

1. Introduction

Atmospheric methane (CH_4) is a greenhouse gas (GHG) which is responsible for around 20% of global warming, whereas CO_2 accounts for up to 60% with the rest contributed from N_2O and other sources (Houghton and Filho, 1996). One major contributor to atmospheric CH_4 accumulation is livestock farming since, globally, the livestock sector produces 37% of all human induced CH_4 (Steinfeld et al., 2006). Methane emissions from livestock originate mainly from enteric fermentation and manure management of cattle production systems. Globally, enteric CH_4 emissions from dairy cows alone account of up to 20% of CH_4 emissions from agriculture, or about 1% of all anthropogenic GHG (Science Daily, 2014). In the USA, cattle emit about 5.5 Tg/year of CH_4 into the atmosphere, accounting for 20% of national CH_4 emissions (Environmental Protection Agency of USA, 2007). Therefore, there is increasing interest in development of CH_4 emission inventories for cattle production systems (e.g. Ominski et al., 2007; Aljaloud et al., 2011; Yan et al., 2010a). However, there is little information available on calculation of CH_4 emissions from enteric fermentation and manure management in different species of large ruminant production systems (dairy cattle, beef cattle, buffalo and yak) in China.

The production systems of large ruminant livestock in China have some special aspects different from those adopted in the rest of the world. China has a unique species of ruminant animals – yaks, which graze yearly around on natural grassland/rangeland in the Qinghai-Tibet Plateau with little concentrate supplementation.

* Corresponding author. Tel.: +44 28 92682484; fax: +44 28 92689594.
E-mail address: Tianhai.yan@afbini.gov.uk (T. Yan).

http://dx.doi.org/10.1016/j.agee.2014.06.002
0167-8809/

Their production level is very low in terms of milk production and growth rate when compared with dairy cows and beef cattle. However, there are no publications in calculation of CH_4 emission inventory for yak production systems in China. The second special aspect of large ruminant production systems in China relates to changes in production systems during the last 30 years, which were driven by increased demand in milk and meat consumption and discontinued use of Chinese yellow cattle (beef cattle) and buffaloes as draft animals. These changes were evidenced with significant increases in dairy cow number and milk production and decreases in population of buffaloes and yaks. Furthermore, large ruminant production in China is localized in accordance with variations in environment, climate and economical conditions. For example, yaks are reared only in the Qinghai-Tibet Plateau, buffaloes in subtropical–tropical areas of Southern China, and dairy cows mainly in surrounding areas of large metropolitan cities. However, there have been no studies to address the effects of these unique aspects on CH_4 emissions from enteric fermentation and manure management with beef cattle, dairy cattle, buffaloes and yaks in China during the last 30 years. The lack of such information can impact the Chinese government's efforts to develop sustainable GHG policies and mitigation strategies to reduce carbon footprint from large ruminant production systems. Therefore, the objectives of the present study were to develop national CH_4 emission inventories for enteric fermentation and manure management for dairy cattle, beef cattle, buffaloes and yaks in China, to evaluate the effect of the economical boom on the inventories from 1988 to 2009 and to identify possible mitigation strategies to reduce CH_4 emissions.

2. Materials and methods

2.1. Data collation

Data used in the present study on animal population, production levels and management regimes for dairy cattle, beef cattle, buffaloes and yaks in China from 1988 to 2009 were obtained from national statistical records (Ministry of Agriculture of China, 1988–2009). The information on dietary ingredient composition and nutritive values of feed ingredients and grazed forages was based on the feeding standards in China for dairy and beef cattle (Agricultural Standards of China, 2004a,b,b). Additional information for yak production systems was obtained from Long (2006). The information on animal physiological states, production levels, dietary ingredient composition, management regimes, feeding strategies and manure management systems was also obtained from a range of farm surveys, scientific publications, internal reports and advices from animal specialists.

2.2. Development of Tier 1CH4 emission inventories

The Tier 1 default CH_4 emission factors of IPCC (2006) for enteric fermentation and manure management were used to develop the inventories for beef cattle, buffaloes and replacements of dairy cattle. However, the default factor of IPCC (2006) for enteric fermentation of dairy cows (68 kg/year) was not adopted, because dairy cows reared in China are Holstein breed which produce a much higher milk yield than that (1650 kg/year) proposed by IPCC (2006) for calculation of the default factor. The CH_4 emission factor used in the present study was 100 kg/year, calculated from annual milk yield per cow in China and the linear relationship between CH_4 default factors and milk yields proposed by IPCC (2006) for use in Northern America, Western Europe and Asia. The CH_4 factor for manure management of dairy cows used in the present study was derived from the default factors of IPCC (2006) for weather conditions in North and South China and dairy cow populations in these two areas. For yaks, IPCC (2006) does not recommend any default CH_4 emission factor for enteric fermentation or manure management. The factors for enteric fermentation and manure management for yaks used in the present study were calculated from those of beef cattle of IPCC (2006) with adjustments of difference in adult live weights between yaks and beef cattle and the poor grazing conditions (weather and grassland/rangeland) experienced by yaks.

2.3. Development of Tier 2 enteric CH4 emission factors

The Tier 2 inventory for dairy cattle, beef cattle, buffaloes or yaks was developed from a sum of sub-inventories within each species, which were derived from subgroups of different physiological states and corresponding Tier 2 emission factors. The latter were calculated from live weights, productivities, diet condition and CH_4 emission rates. The subgroups of each species of large ruminants and the corresponding Tier 2CH4 emission factors are presented in Table 1.

A range of animal and diet factors were required for development of Tier 2 emission factors for enteric fermentation. Data required for milking cows included live weight, milk yield, fat concentration in milk, calving rate, lactation period and dry period. Data required for dry cows and sires included live weight at the beginning and end of each year and for heifers and steers also included birth weight, weaning weight, weaning date and pregnant rate. Net energy (NE) and gross energy (GE) concentrations in rations offered to these large ruminants were also required.

Tier 2CH4 emission factors from enteric fermentation of large ruminants were developed from 4 steps: (1) calculation of NE requirement (NE_{req}) for different functions, i.e. NE requirement for maintenance (NE_m), activity allowance (NE_{act}), milk production (NE_l), live weight gain (NE_g) and foetus growth (NE_p) using Eqs. (1)–(6); (2) conversion of total NE to GE requirements (GE_{req}) using dietary NE and GE concentrations (Eq. (7)); (3) estimation of CH_4 energy emission (CH_4-E) using GE_{req} and CH_4-E as a proportion of GE intake (Eq. (8)); (4) conversion from CH_4-E to CH_4 emission (Eq. (9)). The NE_m was calculated from live weight; NE_l estimated from milk yield; NE_g predicted from growth rate; and NE_p determined from a proportion of NE requirement for maintenance. However, the NE supplied from milk and milk replacers before weaning was excluded. The equations used were based on those of IPCC (2006) and the Chinese feeding standards for dairy and beef cattle (Agricultural Standards of China, 2004a,b,b). The fasting metabolisms of yaks (Long, 2006) and buffaloes (Qin et al., 2011) were also considered.

$$NE_m(MJ/d) = LW(kg) \times NE\ required\ per\ kg\ metabolic\ LW(MJ/kg^{0.75}) \quad (1)$$

where LW = live weight, and NE required per kg metabolic LW = 0.322, 0.386 or 0.370 for non-lactating cows, lactating cows or bulls/growing stock

$$NE_{act}(MJ/d) = C1 \times NE_m(MJ/d) \quad (2)$$

where $C1$ = 0, 0.17 or 0.36 for large ruminants housed in door, grazing on pasture or grazing in a large area

$$NE_1(MJ/d) = Milk\ yield(kg/d) \times (1.47 + 0.40 \times milk\ fatcontent\%) \quad (3)$$

$$NE_g(MJ/d) = 22.02 \times \left(\frac{LW}{(C2 \times MW)}\right)^{0.75} \times WG^{1.097} \quad (4)$$

where MW = mature LW of an adult female (kg), WG = average LW gain (kg/d); $C2$ = 0.8, 1.0 or 1.2 for females, castrates or bulls