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# Modeling methane emissions and methane inventories for cattle production systems in Mexico

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RESUMEN

La fermentación anaeróbica de los carbohidratos estructurales en el rumen de los bovinos genera productos de desecho como ácidos grasos volátiles, calor de fermentación, bióxido de carbono y gas metano. Este último es un gas de invernadero que tiene un potencial varias veces mayor que el $CO_2$ para inducir calentamiento global. El objeto del presente trabajo es aportar una estimación del inventario nacional de metano producido por la fermentación entérica del ganado bovino en México, realizado a partir del uso de un modelo matemático de simulación. Se hizo una clara diferenciación entre el $CH_4$ producido por bovinos que consumen una dieta típica de las regiones tropicales y aquellos que se alimentan con ingredientes de las regiones templadas de México. Se estimó que la emisión total de metano producido por las 23.3 millones de cabezas de bovinos de México asciende a aproximadamente 2.02 Tg/año. Se concluyó que el modelo desarrollado fue apropiado para producir una mejor estimación del inventario nacional de metano producido por el ganado bovino, ya que es lo suficientemente flexible para incorporar nuevos grupos de ganado o esquemas de clasificación, niveles de productividad y una gran variedad de alimentos para el ganado. El modelo también puede utilizarse para evaluar diferentes escenarios de mitigación y servir como herramienta para diseñar políticas de mitigación.

ABSTRACT

Anaerobic fermentation of structural carbohydrates in the rumen of bovines produces waste products such as volatile fatty acids, fermentation heat, carbon dioxide and methane gas. Methane is a greenhouse gas having several times the global warming potential of $CO_2$. The purpose of the present paper is to provide a realistic estimate of the national inventory of methane produced by the enteric fermentation of cattle, based on a simulation model and to provide estimates of $CH_4$ produced by cattle fed typical diets from the tropical and temperate climates of Mexico. Predicted total emission of methane produced by the 23.3 million heads of cattle in Mexico is approximately 2.02 Tg/yr. It was concluded that the modeling approach was suitable in producing a better estimate of the national methane inventory for cattle. It is flexible enough to incorporate more cattle groups or classification schemes, productivity levels and a variety feed ingredients for cattle. The model could also be used to evaluate different mitigation strategies and serve as a tool to design mitigation policies.

**Keywords**: Methane, ruminant, greenhouse gases.

## 1. Introduction

The livestock revolution is driving an increasing world demand of meat and milk from ruminant species (Delgado, 1999). The present challenge for Mexico is to increase ruminant productivity without negatively affecting the environment. Sustainable intensification of smallholder ruminant systems would be a suitable alternative (McDermott *et al.*, 2010). However, feeding of ruminants in these systems is based on the grazing of native pastures and to a lesser extent introduced pastures, usually of poor nutritive value (e.g., low crude protein [CP] content, high neutral detergent fibre [NDF] content, and low digestibility), resulting in low dry matter intake, poor productivity and high methane emissions. High contents of NDF are positively correlated with high $CH_4$ production for dairy and beef cattle (Ellis *et al.*, 2007). Enteric production of methane by livestock is considered a major source of greenhouse gas emissions from the agricultural sector (EPA, 2006). Globally, ruminant livestock produce ~80 million tons of $CH_4$ annually, accounting for ~33% of anthropogenic emissions of $CH_4$ (Beauchemin *et al*., 2009). Methane is an end product of rumen fermentation, formed autotrophically by methanogenic archaea from $CO_2$ and $H_2$ derived from fermentation of carbon sources, basically structural and storage carbohydrates in plants (Orskov *et al*., 1968; Kebreab *et al*., 2006). With a gross energy content of 55.22 MJ/kg, $CH_4$ represents a significant loss of dietary energy from production systems. Typically, about 6-10% of the total gross energy consumed by the dairy cow is converted to $CH_4$ and released into the atmosphere via the breath (Eckard *et al.,* 2010). Therefore, reducing the enteric $CH_4$ production could contribute to decrease overall greenhouse gas emissions on a worldwide scale and lead to production benefits for farmers.

Several studies have been conducted in different countries in order to calculate their national inventories of $CH_4$ emissions by cattle. Blaxter and Clapperton (1965) in the UK were some of the first scientists who attempted to predict $CH_4$ emissions from ruminants. In Australia and New Zealand as well as in Europe and North America, efforts are being made at present to estimate the volumes of $CH_4$ arising from different ruminant production systems (Lassey, 2008; Condor *et al*., 2008; Ellis *et al*., 2009; Martin *et al*., 2010). In Latin America, García-Apaza *et al.* (2008) have estimated $CH_4$ emissions from ruminants in Bolivia. However, there are two or three studies on $CH_4$ emissions from cattle production systems in Mexico. González and Ruiz-Suárez (1995) estimated that in 1990, enteric fermentation from cattle was the source of 1.52 Tg of $CH_4$. The former authors also speculated that by the year 2025 Mexico will have 70 million heads of cattle contributing 2.71 Tg of $CH_4$ per year. However, the assumptions made by these authors may not be correct because cattle population in Mexico has not grown at the rate they had predicted. They assumed that the Mexican cattle population would grow in line with human population. However, results of the 2007 Agricultural Census (INEGI, 2007) demonstrated that the cattle inventory not only did not grow, but it possibly decreased its number. It passed from 31.1 million in 2005 to 23.2 million heads of cattle in 2010. Moreover, these authors did not consider the low quality of the diet consumed by cattle in Mexico, particularly the high proportion of structural carbohydrates such as cellulose in forages, which is known to contribute with a large part of the $CH_4$ produced in the rumen (Moe and Tyrrell, 1979). This is a central issue because low quality forages are the largest part of the cattle's diet in 86% of the Mexican cattle population (INEGI, 2007). Also, large variations in the composition and quality of forages are observed between temperate climate and tropical climate regions of Mexico, the tropics being the region where the quality of the forages is the lowest.

Various methodologies have been proposed to measure *in vivo* methane production in ruminants like respiration chambers, portable analyzers, polythene tunnel, isotope dilution technique and the gas tracer technique (Makkar and Vercoe, 2007). However, none of them is available in Mexico, methane production by cattle never has been measured in vivo in Mexico. The Intergovernmental Panel on Climate Change (IPCC) provides the Guidelines for National Greenhouse Gas Inventories (IPCC, 1996), but when the Tier 1 approach is used methane inventories are not accurate because this method is based on default emission factors that provide a fixed value for each animal species in different regions of the world, irrespective of variation in animal physiological state, production level and diet characteristics (Yan *et al.*, 2011). On the other hand, the Tier 2 approach requires a large quantity of detailed information, which is difficult to gather in some developing countries. So