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Deep litter removal frequency rate influences on greenhouse gas emissions from barns for beef heifers and from manure stores

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A B S T R A C T

The emission of greenhouses gases (GHG) from ruminant production systems needs to be reduced. This can be achieved partly by better manure management, particularly for deep litter (DL) systems. Two contrasting removal frequency rates (1×, every 63.5 ± 3.5 days; and 3×, every 23.1 ± 1.5 days) were compared in a DL system for Belgian blue double-muscled heifers, focusing on CO_2, CH_4 and N_2O emissions from the barn and during two manure storage periods, one mainly in autumn and the other mainly in winter. No significant effect ($p = 0.447$) of manure removal frequency on total GHG emissions was observed (1×: 10.2 ± 3.5; 3×: 8.7 ± 2.2 kg CO_2 eq. kg^{-1} live weight gain).The manure contributed significantly to total GHG emissions (average of 38.9 ± 8.0% of CO_2 eq.), emissions from the barn (4.0 ± 0.7%) and manure store included (34.9 ± 8.7%). Higher emissions (time 4.8 in CO_2 eq.) from manure were observed when it was stored during the warmer period than the colder one. Large variations in emission pattern with the manure removal frequency rates were also observed, leading potentially (not measured) to higher emissions from the 1× treatment than the 3× treatment for a longer storage period than the one tested in this experiment (63 ± 1 days). Given the experimental choices, the variations in emission pattern observed indicated that mitigation options for GHG emissions from the barn and manure store related to manure removal frequency depend on manure storage duration and that keeping deep litter manure in barns without intermediate storage before spreading should be investigated. These options need to be confirmed through emission measurement during and after manure spreading in order to avoid a trade-off between emission stages. The relevance of such options in terms of agronomical concerns needs to be confirmed.

1. Introduction

The effects of human activities on climate change through greenhouse gas (GHG) emissions have been internationally recognised (Intergovernmental Panel on Climate Change and Stocker, 2014) and are the subject of global agreements (UNFCC, 2015). Estimations indicate that agriculture, forestry, land use and land-use change are the source of about 25% of the GHG globally; about 50% of this is from agriculture (Smith et al., 2014), with nitrous oxide (N_2O) and methane (CH_4) being the main contributing gases. In Europe, 45% of the total emissions come from animal husbandry. About 70% of these animal-related emissions originate from cattle systems and 25% from manure in barns or in storage (Freibauer, 2003). N_2O and CH_4 emissions from animal husbandry depend on the microbiological degradation of organic matter. The processes leading to these GHG emissions, however, are influenced by many factors, including O_2 availability, temperature, pH and the amount and characteristics of degradable organic matter (Webb et al., 2012). The diversity of agricultural practices used in herd or manure management is associated with variations in these factors, leading potentially to large differences in GHG emissions from animal husbandry. In a cattle barn, the main source of GHG is the animal itself through the direct emission of CH_4 due to enteric fermentation (Amon et al., 2001; Olesen et al., 2006). Apart from these direct emissions, however, gaseous compounds are also released by manure in the barn, as well as during its storage outside the barn and during or after spreading (Petersen et al., 2013; Snell et al., 2003; Webb et al., 2012; Zhang et al., 2005). The

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importance of considering both barn and storage emissions has been stressed by Külling et al. (2002).

In Wallonia, Belgium, beef and dairy cattle rearing produces mainly solid manure (more than 50%, as indicated by the N distribution in manure (NIR, 2015)). So far as we know (no inventory available), a large proportion of the solid manure is deep litter manure (DL) that is present in facilities for all calves, all fattening bulls and many dairy cows and suckler cows. In this particular manure management system, “faeces or droppings and urine are mixed with large amounts of bedding (e.g., straw, sawdust, wood shavings) and accumulated over a certain time on the floors of buildings housing any type of livestock or poultry” (Pain and Menzi, 2003) before being spread or stored prior to spreading. In DL systems: (1) a large amount of bedding material can be supplied (e.g., 2.9 kg of straw per m^2 per day; Kapuinen, 2001a), increasing the potential amount of nutrients (e.g., C and N) lost as environmentally damaging compounds; and (2) the particular manure characteristics influence organic matter decomposition, at least in the barn, resulting in self-heating, with the manure therefore reaching high temperatures (up to 60 °C; Kapuinen, 2001b), which is related to variations in gaseous emissions from the manure (Husted, 1994; Webb et al., 2012). High emissions of CH_4, N_2O, NH_3 and CO_2, or a trade-off between the emissions of these gases in the barn and during storage, are therefore likely and can be modified through manure management. Choices such as (1) amount of organic material added as litter, (2) frequency of manure removal from the barn and (3) type of bedding material (Petersen et al., 2013) therefore need to be investigated with regard to their impact on manure characteristics and the gaseous emissions from those systems, ideally including the barn, storage and spreading stages. For manure storage outside the barn, it has been reported that emissions of N_2O and CH_4 (Chadwick, 2005; El kader et al., 2007; Webb et al., 2012) from solid manure are a function of manure management that modifies degradation processes, depending on external conditions (e.g., ambient temperature) or manure characteristics (e.g., density, chemical composition). These management options include: amount of straw supplied (Yamulki, 2006); composting (Amon et al., 2001; El kader et al., 2007); and solid manure covering and compaction (Chadwick, 2005). Other management systems leading to seasonal changes in storage ambient conditions and the resulting variations in emissions (Husted, 1994; Mathot et al., 2012) need to be explored at regional level and to include particular climate and management conditions in order to identify efficient GHG emission mitigation options (Sommer et al., 2009). In this respect, in the DL system, as suggested by emission factors from the national GHG inventory (IPCC, 2006), the frequency of removal of solid manure from the barn should be investigated. More information is also needed on CO_2 emissions from solid manure in the barn in order to use total CO_2 emissions as tracer gas for estimating air flows in naturally ventilated barns (Ngwabie et al., 2009).

We set up an experiment that sought to measure N_2O, CH_4 and CO_2 emissions in a barn and during manure storage from beef heifers raised in a DL system (fully strawed barn), based on two removal frequency rates of the manure accumulated in the barn during two climatic periods. The aim of the experiment was to observe the effects of simple manure management options on GHG emissions in DL systems. Variable manure removal frequency could influence manure characteristics and storage conditions and therefore potentially modify GHG emissions. Nutrient flows were also studied in order to validate the observations.

2. Materials and method

This experiment was performed at the same time (and followed the same procedure) as those described by Mathot et al. (2012). Their paper provides a full description of the materials and method. Only the main principles and the particularities of the present experiment are reported here.

The trial was conducted during the 2009–2010 cattle housing period at Libramont (49°55′43″N; 5°21′37″E; altitude 487 m) in Belgium in experimental barns (Fig. 1). The aim was to test the effect of two rates (1× and 3×) of the removal of deep litter manure (DLM) in an experimental DL barn system on GHG emissions and nutrient cycling. Typically, this type of barn is characterised by the accumulation of solid manure below the animals for a fairly long period (up to 6 months), followed by the total removal of the DLM and its storage before it is spread on soil.

The trial was performed over two periods: P1 and P2. During these periods, we raised Belgian blue double-muscled heifers fed with an identical concentrate-rich diet. P1 began in autumn, on 16 November, and P2 in winter, on 8 February, with the solid manure stored outside mainly during the winter in P1 and during the spring in P2 (Fig. 2).

2.1. Barn and storage facilities

The trials were conducted in two experimental loose barns, measuring 25 m^2, with a fully strawed area (16.2 m^2) (Fig. 1). The barns were air tight and mechanically ventilated (1030 m^3/h), with regulation and flow measurements as described by Mathot et al.

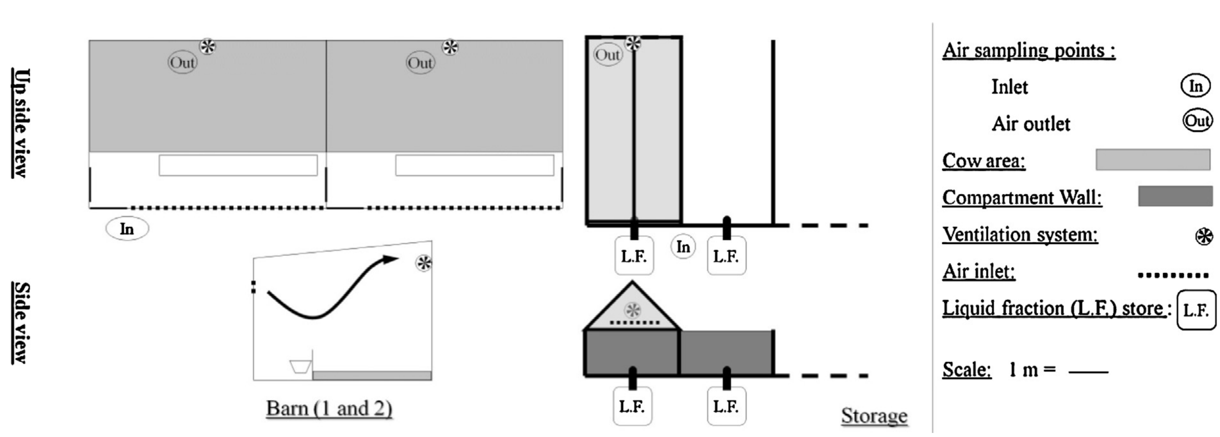

Fig. 1. Barn and manure storage facilities representation. The solid manure storage facility had four compartments, one for each treatment × period (Fig. 2), with a surface area of 11.4 m^2. The compartments were delimited by a 1.2 m-high concrete wall and were each equipped with a liquid fraction collecting system (1 m^3 tank).