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A case study of the carbon footprint of milk from high-performing confinement and grass-based dairy farms

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ABSTRACT

Life-cycle assessment (LCA) is the preferred methodology to assess carbon footprint per unit of milk. The objective of this case study was to apply an LCA method to compare carbon footprints of high-performance confinement and grass-based dairy farms. Physical performance data from research herds were used to quantify carbon footprints of a high-performance Irish grass-based dairy system and a top-performing United Kingdom (UK) confinement dairy system. For the US confinement dairy system, data from the top 5% of herds of a national database were used. Life-cycle assessment was applied using the same dairy farm greenhouse gas (GHG) model for all dairy systems. The model estimated all on- and off-farm GHG sources associated with dairy production until milk is sold from the farm in kilograms of carbon dioxide equivalents (CO_2-eq) and allocated emissions between milk and meat. The carbon footprint of milk was calculated by expressing GHG emissions attributed to milk per tonne of energy-corrected milk (ECM). The comparison showed that when GHG emissions were only attributed to milk, the carbon footprint of milk from the Irish grass-based system (837 kg of CO_2-eq/t of ECM) was 5% lower than the UK confinement system (884 kg of CO_2-eq/t of ECM) and 7% lower than the US confinement system (898 kg of CO_2-eq/t of ECM). However, without grassland carbon sequestration, the grass-based and confinement dairy systems had similar carbon footprints per tonne of ECM. Emission algorithms and allocation of GHG emissions between milk and meat also affected the relative difference and order of dairy system carbon footprints. For instance, depending on the method chosen to allocate emissions between milk and meat, the relative difference between the carbon footprints of grass-based and confinement dairy systems varied by 3 to 22%. This indicates that further harmonization of several aspects of the LCA methodology is required to compare carbon footprints of contrasting dairy systems. In comparison to recent reports that assess the carbon footprint of milk from average Irish, UK, and US dairy systems, this case study indicates that top-performing herds of the respective nations have carbon footprints 27 to 32% lower than average dairy systems. Although differences between studies are partly explained by methodological inconsistency, the comparison suggests that potential exists to reduce the carbon footprint of milk in each of the nations by implementing practices that improve productivity.
Key words: carbon footprint, grass, confinement, milk production

INTRODUCTION

A fundamental objective of milk production is to generate sufficient net farm income for dairy farmers (VandeHaar and St-Pierre, 2006). To achieve this goal in many parts of the developed world, for instance North America, continental Europe, and increasingly in the United Kingdom (**UK**), dairy producers aim to increase farm revenue by maximizing milk yield per cow. This is typically accomplished by offering cows nutritionally precise diets in confinement and through improving genetic merit (Arsenault et al., 2009; Capper et al., 2009). Conversely, in some developed countries, notably Ireland and New Zealand, dairy farmers aim to increase profits by minimizing production costs through maximizing the proportion of grazed grass in the diet of lactating cows (Shalloo et al., 2004; Basset-Mens et al., 2009).

Optimizing resource use has the potential to maximize the profitability of grass-based and confinement dairy systems, and improves the environmental sustainability of milk production (Capper et al., 2009). Thus, a link exists between economic performance and environmental sustainability. In recent years, there has been an increasing focus on evaluating the environmental effects of milk production systems, particularly in relation to greenhouse gas (**GHG**) emissions (Thomas-

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sen et al., 2008; Flysjö et al., 2011b). Dairy production is an important source of the dominant GHG emissions, methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). Globally, milk production generates 2.7% of GHG emissions, with a further 1.3% caused by meat produced from the dairy herd (Gerber et al., 2010). Recent studies suggest that annual global GHG emissions will have to be cut by up to 80% (relative to 1990 levels) before 2050 to prevent the worst effects of climate change (Fisher et al., 2007). However, demand for milk products is projected to double between 2000 and 2050 (Gerber et al., 2010). Thus, reducing GHG emissions (carbon footprint) per unit of milk is becoming a necessity for milk producers.

To assess the carbon footprint of milk from contrasting dairy systems, it is necessary to adopt a life cycle approach. This approach, generally referred to as life-cycle assessment (**LCA**), entails quantifying GHG emissions generated from all stages associated with a product, from raw-material extraction through production, use, recycling, and disposal within the system boundaries (ISO, 2006a,b). Several studies have applied LCA methods to compare carbon footprints of milk from confinement and grass-based dairy farms (Flysjö et al., 2011b; Belflower et al., 2012; O'Brien et al., 2012). However, the results of these studies have been inconsistent.

This inconsistency may be due in part to differences in how GHG emissions are calculated and LCA modeling choices (Flysjö et al., 2011a), but it is also partly due to the farms chosen to represent confinement and grass-based dairy farms. For instance, O'Brien et al. (2012) reported the carbon footprint of milk from a high-performing grass-based dairy system was lower than a confinement dairy system exhibiting moderate performance. Conversely, Belflower et al. (2012) showed that the carbon footprint of milk from a commercial confinement dairy system with a noted record of environmental stewardship was lower than a recently established grass-based system. Generally, LCA studies not biased by the farms selected to represent grass-based and confinement dairy systems have reported that grass-based systems produce milk with a lower carbon footprint (Leip et al., 2010; Flysjö et al., 2011b). However, such studies have only considered average-performing dairy systems. Thus, a need exists to evaluate the carbon footprint of high-performing dairy systems operated at research and commercial farm levels to determine the direction the industry should take to fulfill production and GHG requirements, and to assess their impact on other aspects of the environment, such as fossil fuel depletion and land occupation.

In this study, the primary objective was to compare the carbon footprints of milk from high-performing confinement and intensive grass-based dairy systems using LCA. To achieve this goal, case study farms located in regions accustomed to grass- and confinement-based milk production were selected, namely the United States and UK for confinement dairy systems and Ireland for grass-based milk production. A secondary goal of this study was to assess the effect different LCA modeling methodologies have on the carbon footprints of these contrasting milk production systems.

MATERIALS AND METHODS

Description of Dairy Farming Systems

This study used data from existing reports, published studies, and databases and required no approval from an animal care and use committee. Physical data (Table 1) for quantifying carbon footprints of milk from the Irish (**IRE**) grass-based dairy system and UK confinement dairy system were obtained from research studies (McCarthy et al., 2007; Garnsworthy et al., 2012). The data used for the IRE dairy system was based on a study carried out to analyze the effect of stocking rate and genetic potential of cows on various biological and economic components of grass-based farms from 2002 to 2005. The IRE system fed less concentrate than the average or upper quartile of commercial IRE farms in 2011 (590–850 kg of DM/cow; Hennessey et al., 2012) and outperformed the top quartile of farms for key technical measures such as milk yield (5,914 kg/cow per year) and milk composition (4.1% fat and 3.5% protein).

The data used for the UK dairy system was based on a study used partly to assess enteric CH_4 emissions from cows in 2010 to 2011 (Garnsworthy et al., 2012). The technical performance of the UK system was high compared with the upper quartile of commercial herds in the UK in 2011 for milk yield (8,850 kg/cow per year). However, the UK system fed more concentrate than the average or top quartile of farms (2,666–2,684 kg of DM/cow; McHoul et al., 2012), but produced more milk per kilogram of concentrate. Physical data for the US confinement dairy system was obtained from the DairyMetrics database (DRMS, 2011), and represented the top 5% of herds in 2010 to 2011 for key technical indicators (e.g., milk yield/cow per year).

IRE Grass-Based Dairy System. Milk production in Ireland is based mainly on seasonal-calving grass-based dairy systems. Therefore, the objective of the IRE dairy system was to maximize utilization of grazed grass in the diet of lactating dairy cows. This was accomplished through a combination of extended grazing (early February to late November), tight calving patterns in early spring, and rotational grazing of