J. Dairy Sci. 100:1–17
https://doi.org/10.3168/jds.2016-11909

Effect of feeding strategies and cropping systems on greenhouse gas emission from Wisconsin certified organic dairy farms

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ABSTRACT

Organic agriculture continues to expand in the United States, both in total hectares and market share. However, management practices used by dairy organic producers, and their resulting environmental impacts, vary across farms. This study used a partial life cycle assessment approach to estimate the effect of different feeding strategies and associated crop production on greenhouse gas emissions (GHG) from Wisconsin certified organic dairy farms. Field and livestock-driven emissions were calculated using 2 data sets. One was a 20-yr data set from the Wisconsin Integrated Cropping System Trial documenting management inputs, crop and pasture yields, and soil characteristics, used to estimate field-level emissions from land associated with feed production (row crop and pasture), including N_2O and soil carbon sequestration. The other was a data set summarizing organic farm management in Wisconsin, which was used to estimate replacement heifer emission (CO_2 equivalents), enteric methane (CH_4), and manure management (N_2O and CH_4). Three combinations of corn grain (CG) and soybean (SB) as concentrate (all corn = 100% CG; baseline = 75% CG + 25% SB; half corn = 50% CG + 50% SB) were assigned to each of 4 representative management strategies as determined by survey data. Overall, GHG emissions associated with crop production was 1,297 ± 136 kg of CO_2 equivalents/t of ECM without accounting for soil carbon changes (ΔSC), and GHG emission with ΔSC was 1,457 ± 111 kg of CO_2 equivalents/t of ECM, with greater reliance on pasture resulting in less ΔSC. Higher levels of milk production were a major driver associated with reduction in GHG emission per metric tonne of ECM. Emissions per metric tonne of ECM increased with increasing proportion of SB in the ration; however, including SB in the crop rotation decreased N_2O emission per metric tonne of ECM from cropland due to lower applications of organically approved N fertility inputs. More SB at the expense of CG in the ration reduced enteric CH_4 emission per metric tonne of ECM (because of greater dietary fat content) but increased N_2O emission per metric tonne of ECM from manure (because of greater N content). An increased reliance on pasture for feed at the expense of grain resulted in decreased in milk production, subsequently leading to substantially higher emissions per metric tonne of ECM.
Key words: partial life cycle assessment, carbon footprint, grazing management

INTRODUCTION

The market for organic products continues to expand both in the United States and abroad, reaching approximately $35 billion sales in 2014 (USDA Economic Research Service, 2013). Organic milk demand has recently surpassed available supply, unable to keep pace with consumer demand (McBride and Greene, 2009). As new farms transition to organic production to meet the rising demand for organic milk, farmers likely will need to adjust the feeding strategies used for their conventional herds to achieve the required minimum of 30% DMI from pasture during the grazing season, as outlined by the USDA National Organic Program (USDA, 2013). Within this regulatory framework, however, different approaches relating to both crop production strategy and feed ration composition exist that could be adopted by organic dairy farmers. Wisconsin's organic dairy farms currently exhibit a wide range of these approaches, including varying reliance on pasture or concentrates (Hardie et al., 2014); these farms could serve as models for transitioning producers aspiring to attain specific production, economic, and environmental benchmarks under organic management.

Across all of agriculture, increasing attention has been focused on greenhouse gas (**GHG**) emissions resulting from production practices and their associated effects

Received August 23, 2016.
Accepted March 27, 2017.
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on climate change (IPCC, 2013). Agriculture contributes approximately 9% to total GHG emissions in the United States and 14% of emissions globally (EPA, 2014). Whereas the dairy industry is not a particularly significant source of total global anthropogenic GHG emissions (4% in 2010), the US dairy industry has committed to a 25% reduction of GHG by 2020 relative to 2009 (Innovation Center for US Dairy; http://www.usdairy.com/sustainability/industry-commitment/about). The major sources and sinks of GHG on the dairy farm are associated with crop production (CO_2 and N_2O), enteric fermentation of feed by livestock (CH_4), and manure management (CH_4 and N_2O). Variations in diet formulation, and the associated crop production to supply that diet, can affect the quantity of GHG emissions of the various systems, as highlighted by several studies demonstrating the importance of feed quantity and quality to reduce livestock GHG emission intensity (Johnson and Johnson, 2007; Ogino et al., 2007; Beauchemin et al., 2010; Pelletier et al., 2010).

Life cycle assessment (**LCA**) has been used to evaluate the GHG emissions from dairy operations on a whole-farm level. Studies have compared GHG emissions of confinement-based feeding operations to pasture-based systems, including organically managed systems that include pasture (Cederberg and Mattsson, 2000; Weiske et al., 2006). Several studies indicated that the amount of concentrate fed to dairy herds, and its associated crop production-based GHG emissions and subsequent effects on feed digestibility, enteric methane emissions, and milk productivity (Aguerre et al., 2011; Beauchemin et al., 2008).

As farms make the transition to certified organic practices, critical decisions must be made with respect to feeding strategies and diet composition. Thus, with increasing numbers of dairy operations under organic management, the optimization of feeding strategies provides an opportunity to minimize the carbon footprint of organic dairy farms in Wisconsin while maintaining productivity. Therefore, the objective of our study was to compare the effects of potential feeding strategies and the associated crop hectares on GHG emissions of Wisconsin certified organic dairy farms.

MATERIALS AND METHODS

Feeding Strategies

An analysis from a 2010 survey of Wisconsin certified organic dairy farm management characteristics (Hardie et al., 2014) revealed 4 feeding strategies and production outputs typifying Wisconsin organic dairy farms. Farms were clustered using 9 parameters under 3 general categories: (1) general farm characteristics and management (herd size, percent of Holstein cows, and milking frequency); (2) nonpasture-based feeding practices (number of cow groups, amount of concentrate fed, and feed supplements); and (3) grazing practices (percent of land used as pasture, pasture occupancy period, and grazing season length). Detailed descriptions of herd and management factors for the farms in each of the clusters (number of cows, rolling herd milk average, percent Holstein cows, concentrate fed, land used as pasture, length of grazing season, and average hours per day on pasture) are summarized in Table 1 (Hardie et al., 2014). Greenhouse gas emission allocation between milk and meat was calculated for each cluster, which was based on the weight of meat (bull calf and beef sale) and milk sale (IDF, 2010). Results reported as GHG emission per metric tonne of ECM represented the GHG emission allocated to 1 t of ECM, with exceptions noted in the table footnotes, in which N_2O and CH_4 emission from each emission source and soil carbon loss value were total emission for both milk and meat.

Cluster 1 was composed of 8 farms with an average herd size of 128 cows. The predominate breed in cluster 1 was Holstein, with lesser represented breeds including Jersey, Milking Shorthorn, Brown Swiss, Swedish Red, Normande, Dutch Belted, Linebacks, and Fleckvieh (Hardie, 2013). The lactating cows of the farms described by this cluster heavily relied on supplementation and minimally on pasture. Cow management was the most similar to conventional management strategies among all 4 clusters; it had the least hours per day on pasture compared with the other 3 clusters, low percentage of land designated to pasture, high levels of concentrate feeding, and high DMI. The productivity per cow (i.e., ECM) was second-highest among the clusters.

Cluster 2 was composed of 5 farms with an average of 50 cows each of varying breeds (both purebred and crossbred of Jersey, Milk Shorthorn, Normande, Brown Swiss, Ayrshire, and New Zealand Friesian; only 1 farm had 12% purebred Holsteins; Hardie, 2013) that used seasonal calving. Farms in cluster 2 grazed more days annually than other clusters, had the greatest percent of land under pasture, and used the least amount of concentrate. In part due to seasonal milking, the productivity of these herds was the lowest of all clusters.

Cluster 3 was composed of 32 farms with an average herd size of 41 cows. Similar strategies were used as in cluster 1 for feeding their smaller herds, feeding 6 kg/d of concentrate per cow. Cluster 3 was 89% purebred Holstein; other purebred cows were Jersey and Lineback breeds. The crossbred cows had the genetics of