Effect of Increased Somatic Cell Count and Replacement Rate on Greenhouse Gas Emissions in Norwegian Dairy Herds

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Abstract— Dairy sector contributes around 4% of global greenhouse gas (GHG) emissions, of which 2/3 and 1/3 are attributed to milk and meat production, respectively. The main GHGs released from dairy farms are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). The increased trend in emissions has stimulated research evaluating alternative mitigation options. Much of the work to date has focused on animal breeding, dietary factors and rumen manipulation. There have been little studies assessing the impact of secondary factors such as animal health on emissions at farm level. Production losses associated with udder health are significant. Somatic cell count (SCC) is an indicator on udder health. In Norway, around 45, 60 and 70% of cows in a dairy herd at first, second and third lactation are expected to have SCC of 50,000 cells/ml and above. Another indirect factor is replacement rate. Increasing the replacement rate due to health disorders, infertility and reduced milk yield is likely to increase the total farm emissions. In this study, the impact of elevated SCC (200,000 cells/ml and above) and replacement rate on farm GHG emissions was evaluated. HolosNor, a farm scale model adapting IPCC methodology was used to estimate net farm GHG emissions. Preliminary results indicate an increasing trend in emissions (per kg milk and meat) as the SCC increases. Results suggest that animal health should be considered as an indirect mitigation strategy; however, further studies are required to enable comparisons of different farming systems.

Index Terms—dairy cow, green house gas emissions, HolosNor, somatic cell count.

1 Background

Dairy sector emits around 1970 million tonnes of carbon dioxide equivalent (CO_2-e) emissions every year, which equates 4% of the total global greenhouse gas (GHG) emissions from human activities (FAO, 2010). Whilst 67% of these emissions are attributed to milk production, the remainder is divided into meat production from culled cows (8%) and meat from fattened calves (25%) (FAO, 2010). The major GHGs associated with dairy farming are methane (CH_4), nitrous oxide (N_2O) and the CO_2 (Forster et al., 2007). Methane in livestock is produced from two main sources, namely enteric fermentation and manure management (Brink et al., 2001), accounting for 52% of the global emissions from milk production (FAO, 2010). On the other hand, N_2O emissions originate from either direct emissions from fertilizer and dung and urine or indirect emissions from ammonia volatilisation and nitrate leaching (Eckard, 2010, Erisman et al., 2010). There are also CO_2 emissions associated with fossil fuel use for transportation, and heating and cooling of buildings (Forster et al., 2007).

The global increase in CH_4 and N_2O emissions by 17% between 1990 and 2005 has stimulated thinking and action to reduce the environmental impact of agriculture (Smith et al., 2007). Much of the work to date on mitigating CH_4 emissions has focused on animal manipulation through breeding cows with high feed conversion efficiency (Alford et al., 2006) or diet manipulation through feeding fat and tannins (Clark and Eckard, 2010, Czerkawski et al., 1966) and feed with high digestibility (McAllister and Newbold, 2008). Little research has been conducted to investigate the potential of indirect-strategic factors to reduce GHG emissions from livestock systems. Some of these management-related factors include diseases or animal health (Stott et al., 2010, Williams et al., 2013) and replacement rate (Weiske et al., 2006). Production losses related to udder health are commonly measured by somatic cell count (SCC) (Bartlett et al., 1990). Milk SCC includes mainly white blood cells and epithelial cells and is a commonly used measure to assess the milk quality. It is affected by infection status, age and stage of lactation, and stress and season (Harmon, 1994). Harmon (1994) reported that somatic cell counts of uninfected cows to be less than 200,000. Increased SCC in milk is associated with a decrease in milk production (Bartlett et al., 1990). If a reference value was set to 50,000 cells/ml, the reduction in milk yield may be up to 1.09 and 1,13 kg for a SCC of 600,000 cells/ml in primiparous and multiparous cows, respectively (Hortet et al., 1999). This decrease in milk yield has not been widely questioned from an environmental point of view. In addition, change in GHG emissions due to elevated SCC in different lactation stages requires further evaluation.

In a typical dairy herd, replacement or culling of the milking cows may be necessary due to reduced milk yield, infertility, diseases and other udder, reproductive and health problems (Seegers et al., 1998). Cows should usually be replaced or culled after four lactation and late within lactation to improve the carcass weight of dairy cows (Seegers et al., 1998). Instead of culling the dairy cows earlier, increasing the number of lactations per cow may reduce the net GHG emissions per kg of milk over her lifespan (Hopkins and Lobley, 2009) through emasculating the emissions produced by heifers that are not at all efficient milk producers (Weiske et al., 2006). In addition, keeping the high yielding old cows in the herd may result in reduced CH_4 production (as a proportion of metabolisable energy intake –MEI and per kg) by around 3% than the first parity cows (Bell et al., 2010).

There seems to be lack of research evaluating the relationship between increased SCC, replacement rate and the GHG emissions produced. This study focuses on the method used to demonstrate the impact of varying SCC and replacement rate on GHG emissions produced in Norwegian dairy systems, using a modelling approach.

2 Modelling Greenhouse Gas Emissions

The data regarding milk loss associated with increased SCC were provided by TINE SA, the Norwegian Dairy Product Cooperative. The proportions of the affected animals were calculated according to Svendsen and Heringstad (2006). Markov Chain will be used to account for the change in herd structure in relation to varying SCC and replacement rate (Agrawal and Heady 1974). HolosNor was used to calculate the change in GHG emissions. HolosNor was used to calculate the GHG emissions from combined dairy and beef productions systems (Bonesmo et al., 2013). It is a farm-scale model that estimates net farm GHG emissions from combined dairy and beef farming systems in Norway, accounting for soil C changes. It is based on Holos (Little, 2008), a whole farm model adapting the IPCC methodology with modifications for Canadian livestock and crop production systems to calculate all significant CH_4, N_2O and CO_2 emissions. Holos was modified to recognize Norwegian conditions to consider enteric CH_4, manure-derived CH_4, on-farm N_2O emissions from soils, off-farm N_2O emissions from nitrogen (N) leaching, run-off and volatilization (indirect N_2O), on-farm CO_2 emissions or C sequestration due to soil C changes, CO_2 emissions from energy used on farm, and off-farm CO_2 and N_2O emissions due to supply of feed inputs and N fertiliser. All emissions are expressed as CO_2-eqs to include the global warming potentials recommended by the IPCC on a time horizon of 100 years as 25 kg of CO_2-eq/kg CH_4 and 298 kg of CO_2-eq/kg N_2O (Bonesmo et al., 2013).

The calculations of enteric CH_4 are based on the IPCC Tier 2 approach. The energy required for maintenance, activity, growth, pregnancy and lactation are estimated from the energy content of the feed. The methane conversion factor used to calculate the gross energy intake is 0.065, and energy content of CH_4 is assumed to be 55.64 MJ/kg CH_4. The CH_4 emissions from manure management are based on volatile solids production from both pasture and barn. In order to calculate the CH_4 emission rate, the volatile solid compound is multiplied by a B_0 value, maximum CH_4 producing capacity of the manure. This value is assumed to be 0.24 m^3 CH_4/kg VS for cows and 0.18 m^3 CH_4/kg VS for heifers and young bulls. Direct soil N_2O emissions are estimated from total N input as fertilizer applied, grass and crop residual N and mineralized N. Emission factor is 0.01 N_2O/kg N. The sum of above and below ground residue N gives the residue N whilst a N:C ratio of soil organic matter of 0.1 gives the mineralized N. To calculate direct N_2O emissions from manure, manure N content is multiplied by an emission factor for the manure management system. Indirect N_2O emissions from soil result from leaching and run-off, using a fraction for leaching of 0.3 and emission factor for leaching and run-off of 0.0075 kg N_2O/kg N (Bonesmo et al., 2013). Some preliminary results will be presented at the conference.

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