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Effectiveness of climate change mitigation options considering the amount of meat produced in dairy systems

T.V. Vellinga*, M. de Vries

Wageningen Livestock Research, Wageningen, the Netherlands

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ABSTRACT

Many of the climate change mitigation options for dairy systems that aim at optimizing milk production imply a reduced output of meat from these systems. The objective of this study was to evaluate effectiveness of a number of mitigation strategies for dairy systems, taking into account compensation for changes in the amount of beef produced. Four commonly used mitigation strategies for dairy systems were evaluated using an LCA modelling approach: increasing the milk production per cow, extending the productive life span of cows, increasing the calving interval, and changing breed from Holstein Friesian to Jersey. The Dutch dairy system was taken as a case study. For each scenario, analyses were done in two steps. First, effects of the mitigation strategy on production of milk and carcass weight from the dairy system were calculated. Second, GHG emission intensities were calculated for three different functional units (FU): one kg of fat and protein corrected milk (FPCM), one kg of carcass weight (CW), and a fixed amount of milk and beef (i.e. 1 kg FPCM and 40 g CW). In the third FU, in case the amount of CW produced by the dairy system was lower than 40 g per kg FPCM, the remainder was compensated by CW produced in pure beef systems, assuming a GHG emission intensity of 30 kg CO_2-eq. per kg CW for pure beef. Results showed a reduction in CW per kg FPCM from the dairy system in all four mitigation strategies. Considering GHG emissions per kg of FPCM only, the strategies reduced emissions by 0.2 to 18.1%. When considering emissions per kg of CW only, emissions were reduced by 12.5 to 48.9%. However, when we used a FU of 1 kg FPCM and 40 g CW, changes in emissions ranged from −0.2 to 3.8%. This was caused by the compensation of the lower CW production from dairy systems by CW from pure beef systems. Differences in emissions per kg FPCM and 40 g CW were smaller when the assumed emission intensity of pure beef was lower. We concluded that the mitigation strategies for dairy systems evaluated in this study were less effective for reduction of GHG emissions from production of milk and beef, when accounting for changes in the amount of beef produced. This study showed that the challenge of reducing GHG emissions of milk and beef production is interrelated. Hence, analyses of GHG emissions related to changes in production of milk and beef requires an integrated approach, beyond the system boundaries of the dairy farm.

1. Introduction

Global livestock production is responsible for 14.5% of the total anthropogenic greenhouse gas (GHG) emissions, with beef and milk production contributing to approximately 65% to these emissions (4.6 gigatonnes of CO_2-eq. per year; Gerber et al., 2013; Opio et al., 2013). In most affluent countries, meat and milk are the only outputs of the cattle sector. For these products, literature shows a relatively high GHG emission intensity of animal protein from beef compared to milk, and a relatively wide range of emission intensities from beef due to a large variation in production methods (De Vries and De Boer, 2010).

Because of the large contribution of dairy production systems to climate change, many studies have been performed to evaluate options for mitigation of GHG emissions. Mitigation options for dairy production systems include, for example: i) increasing milk production per cow (Capper et al., 2009; Crosson et al., 2011); ii) increasing productive life spans of cattle and reducing replacement rates (Liang and Cabrera, 2015); iii) reducing the body weights of cows (Capper and Cady, 2012); iv) increasing the lactation period and reducing the calving frequency (a high risk event), hence reducing replacement rates (Lehmann et al., 2014)). All studies point towards reduced maintenance and pregnancy requirements per kg of milk, due to keeping fewer cows for the same amount of milk, fewer young stock to replace cows, fewer calves or less body weight per productive cow.

Many of the mitigation options for dairy production systems aimed at optimizing milk production imply a decreased output of meat from

* Corresponding author at: P.O. Box 338, 6700 AH Wageningen, the Netherlands.
E-mail addresses: theun.vellinga@wur.nl (T.V. Vellinga), marion.devries@wur.nl (M. de Vries).

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dairy systems (Flysjö et al., 2012; Zehetmeier et al., 2012; Lehmann et al., 2014). Milk and meat are interlinked in dairy production systems via the meat production of surplus calves and via culling of adult animals in the dairy herd. Although in intensive dairy systems offspring are often considered to be a by-product, the contribution of dairy systems to global beef supply is significant. In 2013, the fraction of global beef produced in dairy systems was estimated at 45% of the total beef production, with the remainder produced in pure beef systems (with large differences among countries; Opio et al., 2013). In Northwestern Europe and North America, for example, beef consumption is much higher than the amount of beef produced by dairy systems, and the remaining demand is covered by beef from pure beef systems.

Many of the studies that quantified GHG emissions and evaluated mitigation options for dairy production systems used Life Cycle Assessment (LCA). LCA is a generally accepted method for evaluation of environmental impacts during the life cycle of a product (Guinée et al., 2002). LCA studies use allocation rules to attribute GHG emissions to volumes of beef and milk produced. The largest part of GHG emissions from dairy systems are attributed to milk and not to beef (i.e. 83–97%; De Vries et al., 2015). Most of the studies evaluating mitigation options for dairy production systems, however, ignore the fact that a reduced beef output from dairy systems will lead to a reduced availability of dairy-based beef, which will likely be compensated by increased beef production by pure beef systems.

GHG emission intensities of beef produced in pure beef systems are known to be higher than those of beef produced in specialized dairy systems (on average, 70% higher; De Vries et al., 2015). This is mainly because in pure beef systems, all emissions, including those of the maintenance of the mother cow, are allocated to beef only (e.g. Cederberg and Stadig, 2003; Opio et al., 2013; De Vries et al., 2015). As a consequence, compensation of the lower output of beef from dairy production by beef from pure beef systems could contribute to increased GHG emissions from the cattle sector as a whole (Puillet et al., 2014).

A number of studies have demonstrated the importance of considering the reduced output of beef in LCA studies. For example, Flysjö et al. (2012) showed that the compensation of reduced output of beef from dairy systems by beef from pure beef systems will not lead to reduced emissions for the combined production of meat and milk, despite a higher milk production per cow. A similar result was found by Zehetmeier et al. (2012), who also emphasized the importance of considering trade-offs between milk and meat production by showing effects of reproduction and longevity in a later study (Zehetmeier et al., 2014). For beef production within the dairy sector, (crossbred) calf production is found to be an important mitigation option (Hietala et al., 2014; Webb et al., 2014).

To our knowledge, so far no studies have evaluated effectiveness of a range of common mitigation options for dairy systems taking into account the compensation for changes in beef production. At the same time, a strongly increasing global demand for both dairy products and beef underscores the urgent need for mitigation of GHG emissions from cattle production systems (Alexandratos and Bruinsma, 2012). The present study critically evaluates effectiveness of a number of currently suggested mitigation options for dairy systems, taking a more holistic view towards the production and consumption of milk and beef in affluent countries.

The objective of this paper is to evaluate the effectiveness of various common mitigation options for dairy systems aimed at optimizing milk production, taking into account compensation for changes in the amount of beef produced. Four types of mitigation options for dairy systems were evaluated using a modelling approach. The Dutch dairy production system was taken as a case study.

2. Materials and methods

Four types of mitigation options that have been shown to be effective in reducing GHG emissions in dairy production systems in previous studies (e.g. Capper et al., 2009; Crosson et al., 2011; Capper and Cady, 2012; Lehmann et al., 2014; Liang and Cabrera, 2015) were analyzed using a modelling approach: i) increasing milk production per cow, ii) increasing animal productive life span, iii) reducing animals' live weight by using other breeds, and iv) increasing the calving interval. The Dutch dairy system was used as a case study, because this production system was considered representative of intensive dairy systems in North-Western Europe and North America: specialized in milk production, using milk type breeds and working with high levels of external inputs such as compound feeds and fertilizers. GHG emissions of a typical Dutch dairy production system were quantified using LCA. Methodological choices and assumptions for the LCA model, and detailed description of scenarios for each mitigation option are explained in the following paragraphs.

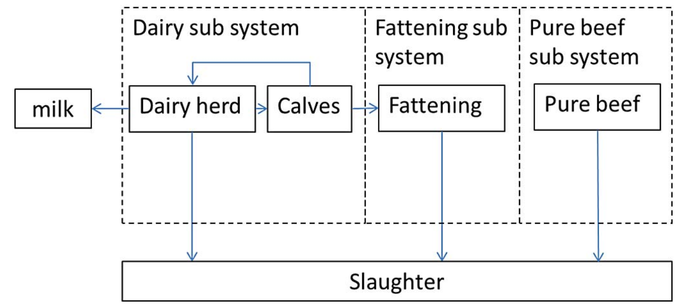

Fig. 1. Schematic representation of production of dairy and beef from the dairy herd and related fattening animals, and from animals raised in pure beef production systems.

2.1. System boundaries and sub system definition

The system analyzed included cradle to farm-gate production stages of dairy and meat production from the dairy herd and related fattening animals, as well as of animals raised in pure beef production systems (Fig. 1). The system producing milk and beef was broken down into three sub-systems: i) a dairy sub-system with adult female cows and replacement young stock, and a small fraction of reproductive males; ii) a fattening sub-system of young surplus male and female animals from the dairy sub-system; and iii) a pure beef sub-system with reproductive stock and fattening animals.

2.1.1. LCA model

The Global Livestock Environmental Assessment Model (GLEAM; Opio et al., 2013, MacLeod et al., 2017) was used for calculating GHG emissions related to beef and milk from the system, assuming a status quo situation (i.e. attributional LCA). Two separate models were built: one for the dairy and fattening sub-systems, and one for the pure beef sub-system. The GLEAM model consists of five different modules, which are described briefly below (more detailed information can be found in Opio et al. (2013).

2.1.2. Herd module

The herd module disaggregates national herd totals in six cohorts of distinct animal classes: female and male reproductive stock, female and male young stock for replacement, and female and male fattening calves (surplus young stock). The herd module calculates the herd structure, the number of animals in each cohort, and the rates at which the animals move from one cohort to another or at which they leave the cohorts. Per cohort, the average weights of animals are calculated, based on the weight at the start and the end of the period in the specific cohort.

The herd module is defined by a set of parameters: i) the fertility rate expressed as number of offspring per adult female animal per year (in this study fertility rate was based on the calving interval), ii)