EIP-AGRI Focus Group
Reducing livestock emissions from cattle farming

Mini-paper - Opportunities to reduce emissions in dairy cattle by animal breeding

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Introduction

Dairy cattle farming significantly contributes to environmental emissions of methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3). Reduction targets defined by governments and/or production chain partners are likely to create incentives for cattle producers to reduce emissions at farm level, especially in situations with increasing total milk production.

One option to reduce emissions is to improve production efficiency. Higher gross efficiency (converting feed into product) reduces emissions in two ways: (1) higher milk yield generally dilutes the maintenance cost of the productive animals and (2) total milk production can be achieved with fewer higher yielding animals and their followers (Wall et al., 2010b). Although dairy farmers hardly considered emission levels in the past, efficiency improvements did also result in largely reduced emissions per kg of product (e.g., Genesis Faraday, 2008; Capper et al., 2009). These efficiency improvements have been the result of improved herd management as well as genetic selection. With the ongoing efforts of dairy breeders to select for improved economic efficiency, emissions are expected to reduce further. This is illustrated by simulation studies predicting that current breeding programmes in the UK and Australia reduce greenhouse gas emissions by 0.6-0.9%/year (Bell et al., 2013 and 2015). With emerging incentives to reduce emissions, breeding strategies that also explicitly consider emissions may better suit future production situations (Berry, 2013). More information on optimising breeding opportunities to reduce emissions will facilitate economical farming while meeting environmental demands. The aim of this paper is therefore to discuss opportunities for animal breeding strategies to further reduce CH_4, N_2O and NH_3 emissions in dairy cattle.

Breeding strategies to reduce emissions

Many dairy cattle breeding goals aim at a simultaneous improvement of milk production and functional traits (health, fertility and longevity). Until now, selection strategies have ignored the effects of changing these traits on emissions. Alternative strategies may consider these effects by (1) optimising the relative weights of currently available information on selection traits and by (2) adding information on traits that affect emissions but have not yet been considered when making selection decisions.

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Optimising use current selection traits

The relative weights of traits in current multi-trait selection indices are often based on bio-economic models that simulate the effect of selection on farm profitability. Weights that result in maximum economic response or desired responses in one or more of the traits of interest are then used to construct the selection index.

Several options may be considered to also include the effect on emissions.

A first option is to include emission costs in the optimisation model. Wall et al. (2014a) evaluated the effect of considering costs of emissions by comparing expected selection responses from economic selection indices, environmental indices and combined indices. When focus was explicitly on emissions (environmental index), annual reductions were up to twice as high as with current economic indices. Environmental indices put relatively more weight on milk production and less on functional traits. The combined indices gave intermediate reductions, depending on the assumed costs of emissions.

A second option is to maximise economic response with a bio-economic model that also restricts emissions at farm level. This method compares to earlier studies where economic values have been estimated for situations with a milk quota system (Groen, 1989).

A third option is to minimise emissions when producing a fixed amount of milk. Van Middelaar et al. (2015) compared the effects of genetic improvement of milk production and longevity in situations that either maximised labour income or minimised greenhouse gas emissions. They confirmed the importance of production efficiency but also indicated that also improved longevity became important when the relevance of reduced greenhouse gas emissions increased.

Adding information on new selection traits

Although direct recording of especially CH_4 emissions at individual animals is technically feasible in, for example, respiration chambers, no large datasets are routinely available for breeding purposes due to practical challenges and high costs. A number of groups therefore focus on more cost-effective methods that measure individual CH_4 emissions in exhaled air using gas quantification equipment, such as 'sniffers' installed in concentrate feeders or automatic milking machines (e.g. Huhtanen et al., 2015a; Hill et al., 2016). Lassen and Løvendahl (2016) found a heritability of 0.21 for data collected using a portable air sampler.

As an alternative to direct recording of emissions, data on traits that affect emissions but have hardly been considered yet may assist in a further reduction of emissions. The relevance of using information on predicted CH_4 emissions, feed efficiency and protein efficiency is discussed below.

- Predicted CH_4 emissions. Several groups have focussed on using information from individual milk samples to predict CH_4 emissions. In a recent meta-study, Van Lingen et al. (2014) estimated that variation in fatty acid profiles of milk samples may explain almost 50% of the variation in CH_4 emissions per kg of milk. Using the prediction regressions from the meta-study, Van Engelen et al. (2015) estimated heritabilities for predicted CH_4 heifers from 0.12 to 0.44. As a cheaper alternative to the costly gas chromatographic analyses to measure fatty acid profiles, the value of infrared spectral data of milk samples as a cost-effective source of information has also been studied (Dehareng et al., 2012). In a small dataset, Vanlierde et al. (2016) found that mid-infrared spectra could explain 70% of daily CH_4 emissions of an animal. Kandel et al. (2014) estimated a heritability of 0.21 for predicted emissions based on mid-infrared data.

- Feed efficiency. Improved feed efficiency (kg milk / kg feed) is expected to have a large favourable effect on environmental efficiency as production and consumption of feed significantly contribute to emissions (e.g. Connor, 2015). In the past, direct selection for feed efficiency was very limited as large-scale recording of individual feed intake data is technically demanding and expensive. Recent developments such as higher feed costs and new genomic techniques have increased interest in new methods to record and analyse feed intake data. Several international activities such as the Global Dry-Matter Intake project have focussed on producing reliable estimates of individual breeding values by pooling data and/or developing genomic evaluations (De Haas et al., 2015). Although information on routinely recorded data such as milk production and body weight explain a large proportion of the genetic variation in feed efficiency (Berry and Crowley, 2014), more reliable information on feed efficiency can contribute to a significant improvement of economic and environmental efficiency (e.g. Basarab et al., 2013).

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- Protein efficiency. One option to reduce N_2O and NH_3 emissions from nitrogen excretions is to improve protein or nitrogen efficiency of milk production (Castillot et al., 2000). As direct observations on excretions are not easily available for breeding purposes, related traits such as protein efficiency or urea content in milk may be used as an alternative.
  Genetic studies on protein efficiency in dairy cattle are relatively scarce. Vallimont et al. (2011) estimated a heritability for crude protein efficiency of 0.21 with a high positive correlation with protein yield. These results indicate that improvement of protein efficiency based on protein efficiency data is possible as well as that selection for higher protein yield indirectly also improves protein efficiency. Dijkstra et al. (2013) showed that higher milk yields result in higher milk nitrogen efficiencies but that this improvement is relatively smaller than the effect of on feed efficiency.
  As a large proportion of excreted nitrogen is urinary urea nitrogen, the use of milk urea nitrogen (MUN) data has also been suggested to select for lower nitrogen excretions. Selection for lower MUN content seems to be attractive as MUN data are routinely available in many milk recording schemes and show clear genetic variation. However, Spek et al. (2013) concluded in a review, that estimated breeding values for MUN are unrelated to efficiency of nitrogen utilisation and probably to urinary urea nitrogen as well. Also Huhtanen et al. (2015a) concluded that genetic differences in MUN are extremely small compared to variation in diet composition, which means that genetic selection for lower MUN will have very limited effect in practice.

Discussion

While emissions in dairy and beef production have hardly been an issue until now, the more stringent environmental policies that are being implemented are expected to create incentives for farmers and other stakeholders in the production chain reduce emissions. Direct incentives for reduced emissions, however, are currently hardly present which may cause farmers and stakeholders reluctant to invest in innovations that reduce emissions. More detailed information on how new policies affect future incentives will facilitate the evaluation of the cost-effectiveness of current and future innovations.

Animal breeding is one of the tools farmers can consider to improve environmental efficiency at farm and at national level. Although the effects of animal breeding on emissions may not be immediately visible in contrast to changes in nutrition, housing, manure management and other management interventions, selection responses are cumulative and permanent and breeding options are therefore cost efficient (Wall et al., 2010b).
Although several recent papers indicate that animal breeding can further decrease emissions, optimisation of current practical selection strategies remains challenging. A first challenge is to adequately weight the relevance of reduced emissions compared to the genetic improvements of other traits, especially when (monetary) benefits of reduced emissions for farmers are not obvious. Once the relative importance of reduced emissions has been identified, the second challenge is defining the optimum selection strategy given the genetic parameters (heritabilities and genetic correlations) and the availability of data. More information on the relations of emission traits with other traits of interest, especially with functional traits, will help to better evaluate predicted selection response. Studies indicating the favourable effects of improving fertility on emissions (e.g. Garnsworthy, 2004, Cottle et al., 2011) may suggest that combined strategies that also consider emissions will result in higher selection responses for fertility traits. First studies on selection indices, however, have indicated that with a higher emphasis on reduced emissions genetic improvement of fitness traits will be smaller than in current strategies (Wall et al., 2010a; Kandel et al., 2014).

This study focussed on selection strategies in dairy cattle. Although fewer studies on beef cattle have been published, several conclusions may also be valid for beef cattle. Also in beef cattle selection for production efficiency has resulted in reduced emissions per unit of beef. Åby et al. (2013) indicated that breeding objectives considering both production and functional traits will not be changed considerably in combined selection indices that also consider emissions. A study from the UK (Defra, 2012) indicated that extensive data recording systems of feed intake and carcass data would increase the current annual emission reduction from 0.3 to 1.0%. Using direct information on CH_4 in beef cattle is generally more complicated than in dairy cattle, especially when animals are managed in extensive grazing systems. Current developments include measuring CH_4 using laser device with grazing cattle (e.g. Ricci et al., 2014) or with a methane hood system in confined beef cattle (e.g., Troy et al., 2016).

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A lot of work on emissions in cattle breeding has so far focussed on CH_4 emissions whereas available genetic information on N_2O and NH_3 emissions is limited. To some extent these emissions are expected to be reduced as an indirect result of selection for improved fertility (e.g. Garnsworthy, 2004) and feed efficiency.

This mini-paper shows that improved feed efficiency and protein efficiency largely affect emissions, but that maximum selection response for these traits is not realised in practice due to limited information on individual variation. It is therefore beneficial to invest in studies on new methods and techniques that accelerate genetic improvement of these traits. Preferably these studies would also consider the effects of the increasing global demand for animal protein on the availability and costs of raw materials (Hayes et al., 2013).
Many studies have evaluated options to collect and evaluate data for breeding purposes. Due to high experimental costs and complex relationships between genetics and physiology, pre-competitive multidisciplinary collaboration across countries has been very helpful. Examples of such collaborative efforts in Europe include FP7 projects (Ruminomics, GreenhouseMilk, GPlusE, RedNex, AnimalChange) and COST actions (Methagene).

Conclusions

- Past and current animal breeding strategies for improved production efficiency have indirectly also significantly reduced emissions.
- Emissions may be further reduced when selection includes more information on emissions or on related traits.
- Breeding strategies that explicitly emissions have not yet been implemented. Unclear incentives for farmers as well as limited information on the relations between emissions and other traits limit fast and cost-efficient uptake of breeding innovations.

We recommend:

- More discussions with farmers and stakeholders on the current and future incentives to reduce emissions.
- More international exchange of information on methods and best practices regarding collection and use of emission data in breeding programmes.

Proposal for potential operational groups

Collecting methane emission data on farm: the best tools and practices.

Proposals for (research) needs from practice

- Use genomic information to estimate genomic breeding values (GEBVs) for CH4 emissions into breeding schemes.
- Scenario studies evaluating optimal combined selection strategy for dairy and beef farmers.

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