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Effect of feed-related farm characteristics on relative values of genetic traits in dairy cows to reduce greenhouse gas emissions along the chain

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ABSTRACT

Breeding has the potential to reduce greenhouse gas (GHG) emissions from dairy farming. Evaluating the effect of a 1-unit change (i.e., 1 genetic standard deviation improvement) in genetic traits on GHG emissions along the chain provides insight into the relative importance of genetic traits to reduce GHG emissions. Relative GHG values of genetic traits, however, might depend on feed-related farm characteristics. The objective of this study was to evaluate the effect of feed-related farm characteristics on GHG values by comparing the values of milk yield and longevity for an efficient farm and a less efficient farm. The less efficient farm did not apply precision feeding and had lower feed production per hectare than the efficient farm. Greenhouse gas values of milk yield and longevity were calculated by using a whole-farm model and 2 different optimization methods. Method 1 optimized farm management before and after a change in genetic trait by maximizing labor income; the effect on GHG emissions (i.e., from production of farm inputs up to the farm gate) was considered a side effect. Method 2 optimized farm management after a change in genetic trait by minimizing GHG emissions per kilogram of milk while maintaining labor income and milk production at least at the level before the change in trait; the effect on labor income was considered a side effect. Based on maximizing labor income (method 1), GHG values of milk yield and longevity were, respectively, 279 and 143 kg of CO_2 equivalents (CO_2e)/unit change per cow per year on the less efficient farm, and 247 and 210 kg of CO_2e/unit change per cow per year on the efficient farm. Based on minimizing GHG emissions (method 2), GHG values of milk yield and longevity were, respectively, 538 and 563 kg of CO_2e/unit change per cow per year on the less efficient farm, and 453 and 441 kg of CO_2e/unit change per cow per year on the efficient farm. Sensitivity analysis showed that, for both methods, the absolute effect of a change in genetic trait depends on model inputs, including prices and emission factors. Substantial changes in relative importance between traits due to a change in model inputs occurred only in case of maximizing labor income. We concluded that assumptions regarding feed-related farm characteristics affect the absolute level of GHG values, as well as the relative importance of traits to reduce emissions when using a method based on maximizing labor income. This is because optimizing farm management based on maximizing labor income does not give any incentive for lowering GHG emissions. When using a method based on minimizing GHG emissions, feed-related farm characteristics affected the absolute level of the GHG values, but the relative importance of the traits scarcely changed: at each level of efficiency, milk yield and longevity were equally important.

Key words: breeding, milk yield, longevity, economic value

INTRODUCTION

Dairy cattle breeding has the potential to reduce greenhouse gas (**GHG**) emissions from dairy farming (e.g., Hayes et al., 2013). Breeding for increased animal productivity, for example, reduces the number of animals needed to produce the same amount of product and is seen as an important strategy to reduce GHG emissions (Hristov et al., 2013). In contrast to most other types of management strategies, such as dietary changes, breeding is a long-term strategy, with permanent and cumulative effects. This implies that good planning is essential when deciding on a breeding strategy.

Most studies that have explored breeding strategies to reduce GHG emissions focused on reducing the emissions of enteric CH_4 (Bell et al., 2010; De Haas et al., 2011; Hansen Axelsson et al., 2013). Genetic improvement, however, can affect the whole farm, including the diet of dairy cows and on-farm feed production (Bell et

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al., 2010; Wall et al., 2010). As a result, not only enteric CH_4 but also other GHG emissions related to characteristics of cows and activities on the dairy farm might change. In addition, a strategy can affect the type and amount of purchased products, such as feed and fertilizers. Hence, GHG emissions related to production of farm inputs might change as well. Evaluating the effect of a genetic improvement, therefore, requires an integrated approach that accounts for changes in farm management and includes all GHG emissions along the chain; that is, from production of farm inputs up to the farm gate (Wall et al., 2010; Van Middelaar et al., 2013a, 2014).

Evaluating the effect of a 1-unit change in genetic traits on GHG emissions along the chain (i.e., from production of farm inputs up to the farm gate) provides insight into the potential effect of individual traits to reduce GHG emissions (Van Middelaar et al., 2014). Such "GHG values" can be used to implement environmental performance of traits in breeding programs (Wall et al., 2010). Van Middelaar et al. (2014) examined 2 methods to calculate GHG values of genetic traits by using a whole-farm optimization model in combination with a life cycle approach (i.e., including all GHG emissions up to the farm gate). The first method optimized farm management before and after a change in genetic trait by maximizing labor income; the effect on GHG emissions was considered a side effect. The second method optimized farm management after a change in genetic merit by minimizing GHG emissions per kilogram of milk, while maintaining labor income and milk production at least at the level before the change in trait. The effect of methods was illustrated for an improvement of 1 genetic standard deviation in milk yield and in longevity. It was shown that GHG values of both traits were about twice as high when the focus was on minimizing GHG emissions than when the focus was on maximizing labor income. In addition, GHG values of milk yield were larger than GHG values of longevity, especially when focus was on maximizing labor income.

The GHG values calculated by Van Middelaar et al. (2014) applied to one typical dairy farm in 2020, with high efficiency concerning feed utilization and feed production at farm level. High efficiency in feed utilization was obtained by ignoring safety margins for true protein digested in the small intestine (**DVE**) and for rumen degradable protein balance (**RDPB**). Such an increase in efficiency might be reached by precision feeding. High efficiency in on-farm feed production was obtained by increasing grass and maize yields per hectare based on historical data analysis to estimate yields for 2020. Several studies have shown, however, that the environmental impact of milk production varies between farms, and that this variation is often feed-related (Thomassen et al., 2009; Meul et al., 2014). Examples of feed-related farm characteristics causing variation in GHG emissions are type and amount of feed used per cow, level of crop yield per hectare, and level of nitrogen application for on-farm roughage production (Thomassen et al., 2009; Meul et al., 2014). It is unclear how GHG values of genetic traits depend on feed-related farm characteristics (i.e., no precision feeding, lower yield per hectare).

The objective of this study was to explore the robustness of GHG values to assumptions on feed-related farm characteristics. The GHG values of milk yield and longevity were calculated for a less efficient farm and compared with those calculated for an efficient farm by Van Middelaar et al. (2014). The less efficient farm does not apply precision feeding and has a lower grass and maize yield per hectare than the efficient farm.

MATERIALS AND METHODS

Methods used to calculate GHG values of milk yield and longevity are described in detail in Van Middelaar et al. (2014). The following paragraphs include a short description of the most important aspects of the model and a description of the analysis to determine GHG values. Differences between the efficient and less efficient farm are explained.

The aggregate genotype for our analysis consisted of milk yield and longevity; genetic variation in other traits was ignored. The relative GHG value of a genetic trait represents the effect of a 1-unit change on GHG emissions at the chain level while keeping the other trait constant. The chain level included all processes related to milk production from the production of raw materials to produce farm inputs (e.g., feed and fertilizers) until the moment the milk leaves the farm gate. Results (income and GHG emissions) for the optimized farm before and after 1 standard deviation improvement of milk yield (longevity) were determined using a dairy farm linear programming (**LP**) model. Two methods were used for optimization. Method 1 optimized farm management by maximizing labor income, while the effect on GHG emissions was considered a side effect. This method is similar to that used to calculate economic values. Economic values express the change in economic efficiency of a farming system that result from genetic improvement of individual traits and form the basis for current breeding goals in dairy farming (e.g., Groen, 1988; Hietala et al., 2014). Method 2 optimized farm management by minimizing GHG emissions per kilogram of milk while maintaining not only labor income but also milk production from the herd at least at the level before the change trait. This method, therefore, shows what could be achieved if breeding results

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