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Effect of incorporating greenhouse gas emission costs into economic values of traits for intensive and extensive beef cattle breeds

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ABSTRACT

Ruminants contribute considerably to the Greenhouse Gas (GHG) emissions from agriculture. Genetic improvements have a large potential through permanente and cumulative reductions in emissions. Currently, indirect selection through correlated traits considered in broad breeding goals is the best option for reducing emissions. Breeding goal traits are weighed by their respective economic value (EV). The emission of GHG may be included in the bio-economic model, and the costs of GHG emissions may be estimated and included in the calculation of economic values using a shadow price. In this study emission costs were included in the calculations of economic values for two breed group under three production conditions; (1) semi-intensive (2) completely roughage based (RB) and (3) minimum use of concentrates (MC). Three harvested roughage qualities (early, medium and late cut) were included in the two latter situations, giving a total of 14 situations. EV were estimated for seven functional traits: herd life of cow (HL), age at first calving (AFC), calving interval, stillbirth (S), twinning rate (T), calving difficulty, limb and claw disorders, and for seven production traits: birth weight, carcass weight, carcass conformation, carcass fatness, growth rate from birth to 200 days (weaning), growth rate from 200 to 365 days and growth rate from 365 days to slaughter. Including GHG emissions into calculation of economic values (EV) decreased the relative economic importance of the functional traits HL, AFC, S and T, while increasing the importance of the production traits. However, the overall effect of including GHG emission was small and little reranking between the traits was observed. A sensitivity analysis for increased shadow price showed small effects on the EV. The results suggest that the economic values are robust towards the inclusion of GHG emission costs into the profit equation and also towards increased shadow price. Thus, broad breeding goals for beef cattle including both production and functional traits do not need to be changed considerably to take the emission of GHG into account.

1. Introduction

Agriculture contributes considerable to the anthropogenic Green House Gas (GHG) emissions. In the European Union, agriculture is the second largest source of GHG emissions, accounting for 10% of the total emissions. Methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) are the three most important GHG (UNFCCC, 2011). Livestock, especially ruminants, are important contributers to the amount of the emissions from agriculture (FAO, 2006). Therefore, livestock production plays an important role if GHG emissions from the agricultural sector are to be reduced.

Several management and feeding practices to reduce methane emissions have been proposed; e.g., feed additives,

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vaccination, diet manipulation and use of inoculants and acetogens (Cottle et al., 2011). Genetic improvements have a large potential through permanent and cumulative reductions in emissions. The aim of including mitigation in breeding objectives should be to reduce the emission per kg of product and may be done in several ways (Wall et al., 2010). An obvious approach is direct selection for reduced emissions. Another approach is through indirect selection by improving animal efficiency and productivity and reducing animal wastage (Wall et al., 2010). This indicates the development of broad breeding goals including both production and functional traits (Wall et al., 2010) which concur nicely to the current trend in breeding goal developments in many breeds. Direct selection for reduced emissions suggests direct measurement on GHG emissions for large numbers of animals, which obviously is very timeconsuming and expensive. Thus, indirect selection based on correlated traits already considered in broad breeding goals seems currently to be the best option for including GHG emissions in breeding goals. However; the genetic correlations between direct emissions and indicator traits are currently unknown. Direct GHG emissions are also around the corner, for example measuring methane emissions by using breath measurements (Lassen et al., 2012).

Usually, the traits included in the breeding objective are weighed by their economic value, which is estimated as the change in profit from a unit change in the trait considered using e.g., bio-economic models (e.g., Phocas et al., 1998; Wolfova et al., 2005; Åby et al., 2012a). Likewise, GHG emissions are estimated using similar models, and the change in emissions resulting from improvement in some of the considered traits are calculated (e.g., Beauchemin et al., 2011; Garnsworthy, 2004; Ogino et al., 2007). To calculate the cost of the GHG emissions from an environmental economics point of view, a shadow price per ton of CO_2-equivalent may be defined (DEFRA, 2007). Finally, by incorporating the GHG emission costs into bio-economic models, alternative economic values may be calculated (Wall et al., 2010). These authors used this approach to calculate environmental economic values in dairy cattle; however this approach has not yet been used in beef cattle.

Climate change and human population growth may force beef production into more extensive, roughage based systems due to limited availablility of grain (Beauchemin et al., 2010). This will influence the GHG emissions and thus their associated costs. Therefore, the effect of changed production conditions on the environmental economic values should be investigated.

The aim of this study was to incorporate the cost of GHG emissions into the calculation of economic values for production and functional traits for beef cattle, using a bio-economic model considering both current and alternative production conditions.

2. Materials and methods

2.1. The model, included traits, profit functions and production conditions

The deterministic model follows one suckler cow and progeny through the cow's life cycle. Two breed groups are defined; intensive (i.e., Charolais, Simmental and Limousin) and extensive (i.e., Hereford and Aberdeen Angus) with differences in performance, economy and other input factors. The intensive breed group was characterised by higher performance for the production traits and lower performance for the functional traits, and a higher proportion of concentrates and cultivated pasture in the diet. In addition a higher proportion of labour was used for feeding and tending of animal and inspections during calving, compared to the extensive breed group. In contrast, the extensive breed group was defined by a lower performance for the production traits and higher performance for the functional traits, a larger amount of roughage and uncultivated pasture in the diet and a higher proportion of labour used for roughage harvesting, manure handling and maintenance of buildings and machinery (Åby et al., 2012a).

A total of 14 traits were included in the model: seven production and seven functional traits. The production traits were: birth weight (kg), carcass weight (kg), carcass conformation (class), carcass fatness (group) and growth rate (gram per day) in three periods: (1) from birth to weaning at 200 days of age, (2) from weaning to 365 days, and (3) from 365 days to slaughter. The functional traits were: herd life of cow (days), age at first calving (days), calving interval (days), calving difficulty (score), stillbirth (%), twinning frequency (%) and limb and claw disoders (%).

The profit function and calculation of economic values is described in detail in Åby et al. (2012a). Income comes from slaughter animals and subsidies. In the present study, the cost of GHG emissions is included in the profit function in addition to the cost of feed, labour, calving difficulty and limb and claw disorders. The marginal economic values (EV_n) were estimated as the change in profit resulting from a 0.1% increase in the mean of the considered trait while keeping the mean of all other traits constant, and then expressed per unit increase of the trait (e.g., per kg or day). The economic values were expressed per suckler cow and year. Relative economic values (REV, in %) were estimated by using Eq. (1) (Åby et al., 2013)

$$REV_i = \frac{|EV_i * \sigma_i|}{\sum_{i=1}^{n} |EV_i * \sigma_i|} \times 100 \quad (1)$$

where σ_i is the genetic standard deviation of the n*th* trait.

Three alternative production conditions were investigated in this study, one semi-intensive and two extensive. The semi-intensive was the basis situation (BAS) described in Åby et al. (2012a). This production condition was characterised by intensive feeding of bulls and surplus heifers, using considerable amounts of concentrates and a more extensive suckler cow–calf enterprice. In addition, two extensive production conditions were included (Åby et al., 2013); one completely roughage based production (RB) and one with minimum use of concentrates (MC). In both of the extensive situations, three roughage qualities were used: early (6.56 MJ NE/kg DM), medium (5.87 MJ NE/kg DM) and late cut (5.18 MJ NE/kg DM). This gave a total of 14 included situations. In the MC situation a small amount of concentrates were given to bulls and replacement heifers. Due to differences in feed intake between the included situations, the performance (i.e., growth rate) of the bulls, surplus heifers and replacement