A method to define sustainable breeding goals for livestock breeding programmes

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ABSTRACT

The objective was to present a method to define sustainable breeding goals. Sustainable breeding goals can be defined by adding non-market values to the market economic values for functional traits in the breeding goal. A non-market value can represent the value of improved animal welfare or societal influences for animal production. The consequence of adding a non-market value to a functional trait is less selection response in production traits. Deterministic simulations and selection index theory were used to derive non-market values based on the loss in selection response for production traits, farmers and/or breeding companies are willing to loose to improve functional traits. The method was demonstrated using a breeding goal for dairy cattle with three traits (milk yield, mastitis resistance, and conception rate). Applied market economic values were 148, 163 and 65 € per phenotypic standard deviation. With a breeding goal with market economic values only for all three traits, selection response for milk yield, mastitis resistance and conception rate were 141.5, -7.4 and -5.1 € giving a total selection response of 129 €. With 5 percent loss (7.1 €) in selection response for milk yield, response for mastitis resistance and conception rate were -2.1 and -4.1 € and total selection response was 128.2 €. Simultaneously derived non-market values with 5 percent loss in selection response for milk yield were 42 € for mastitis resistance and 16.7 € for conception rate. These combinations of non-market values are the values, which maximize total selection response. It was concluded that it is possible to improve functional traits by adding a non-market value to the market economic values without high losses in total selection response and that the method can be used to derive non-market values in order to define sustainable breeding goals.

INTRODUCTION

Livestock breeding programmes have primarily focused on improving production traits. Selection for production traits only will lead to deterioration of functional traits such as increased disease incidence and decreased fertility (Rauw et al., 1998). In addition, including a functional trait in a breeding goal and assigning an economic value to the traits is no guarantee for genetic improvement in the trait. This is because most production and functional traits are negatively genetically correlated and most functional traits have low heritabilities. Finally, genetic improvement for functional traits is complicated because increased selection emphasis on functional traits leads to decreased genetic improvement for production traits.

Recently sustainable livestock production has received increased attention especially in the Western part of the world. As reviewed by Sandøe (2003) many different definitions of sustainability have been used. Torp Donner and Juga (1997) defines it as ecological production, which takes environment and biodiversity into account and is ethically and economically sustainable. Sustainable breeding should therefore contain these factors. It is clear from the definition of sustainability, that negative side-effects of selection for production traits are in conflict with animal welfare (Sandøe et al., 1999), and thus with the term sustainability.

The traditionally methods to define breeding goals using profit equations (e.g. Brascamp et al., 1985) with the objective to maximize the profit of the farmer do not integrate the concept of sustainability of farm animal production. Olesen al. (2000) suggested including a "non-market" in addition to the market economic value in the breeding goal to consider the value of improved animal welfare and social aspects. However, even though tools for deriving non-market values have been proposed (Olesen et al., 1999) only few examples showing how to assign non-market to traits are found in the literature (e.g. Kanis et al., 2005; Nielsen et al., 2005). Hence, there is a need to develop methods to define sustainable breeding goals including multiple functional traits.

Therefore the objective of this study was to develop a method to define sustainable breeding goal including multiple functional traits. In this paper we extend the method by Nielsen et al. (2005) to include the derivation of non-market values for multiple functional traits based on the trade-off between selection response for a production trait and selection response for functional traits. The method is illustrated using dairy cattle as an example.

MATERIAL AND METHODS

Breeding goal, Genetic and Economic Parameters

The following three traits were included in the breeding goal; milk yield, mastitis resistance and conception rate. Milk yield was weighted only by a market economic value, whereas mastitis resistance and conception rate were weighted by both a market economic value and a non-market value. The breeding goal (H) can then be written as

$$H = EV_{MY} \times Y_{MY} + (EV_{MR} + NV_{MR}) \times Y_{MR} + (EV_{CR} + NV_{CR}) \times Y_{CR} \quad (1)$$

Where EV is a market economic value for milk yield (MY), mastitis resistance (MR), and conception rate (CR), NV is a non-market value for MR and CR, NV + EV is a goal value (GV), and Y is a genetic value for MY, MR, and CR, respectively.

In this study we only considered the selection paths of progeny tested sires to breed cows and sires, respectively. The progeny group per sire was assumed to be 100 daughters and 5% of tested bulls were selected. Assumed heritabilities, genetic and phenotypic correlations (Sørensen, 1999) and market economic values (Nielsen, 2004) are given in Table 1.

Table 1. Assumed genetic, phenotypic and economic parameters for milk yield, mastitis resistance and conception rate. Heritabilities (diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal).

Trait[1]	Milk yield	Mastitis resistance	Conception rate	σ_P^2	Market economic value[3]
Milk yield	0.28	-0.35	-0.35	530	0.28
Mastitis resistance	0.03	0.04	0.20	1	163
Conception rate	-0.10	0	0.03	33	1.98

[1]Units: Milk: (kg·cow^{-1}·year^{-1}); Mastitis: (incidence·cow^{-1}·year^{-1}); Conception rate: (%·cow^{-1}·year^{-1})
[2]Phenotypic standard deviation. [3]€ ·unit.

Prediction of Selection Response

In this study, selection response was defined as genetic superiority of selected bulls after one round of selection. Selection response for each trait T was:

$$\Delta G_T = \frac{\sigma_{IT}}{\sigma_I} \times i$$

where, σ_{IT} is the covariance between index and trait T, i is the selection intensity, and σ_I is the standard deviation of the index.

Toal selection response in monetary units (ΔG) is the sum of selection response for all traits in the breeding goal valued by market economic values for each trait (EV_T):

$$\Delta G = \sum_{i=1}^{T} EV_T \times \Delta G_T$$

Derivation of Non-market Values

The applied method was based on selection index theory and is an extension of the method described by Nielsen et al. (2005). The method was based on the trade-off between selection response for production and selection response for functional traits. This trade-off between response for production and functional traits is due to the fact that increasing selection emphasis on functional traits results in reduced selection response for those production traits, which are negatively correlated to the functional traits.

Firstly, selection response was calculated using the above described breeding plan and breeding goal (1) with market economic values as given in Table 1 and assuming zero non-market values for both mastitis resistance and conception rate. Secondly, percent loss (PCTL) in selection response for milk was defined as selection response for milk yield for a breeding goal containing both market economic values and non-market values relative to selection response for milk yield for a breeding goal containing market economic values only:

$$PCTL_i = \frac{\Delta G_{MAX} - \Delta G_{NV_i}}{\Delta G_{MAX}} \times 100 \iff \Delta G_{NV\,i} = \Delta G_{MAX} - (PCTL_i \times \Delta G_{MAX}), \text{ i=1, ..,30}$$

Where, ΔG_{MAX} is selection response for milk using breeding goal (1) with zero non-market values for both mastitis resistance and conception rate, ΔG_{NVi} is selection response for milk yield for *i*th percent loss for a breeding goal including both market economic values and non-market values for mastitis resistance and conception rate. Next, changes in ΔG_{NVi} were restricted to correspond to *i*th loss. For each loss i, goal values for mastitis resistance and conception rate (NV + EV) were then found by optimizing the index according to maximum change in total selection response in monetary units and non-market values were derived as the difference between the goal values and the market economic values. By deciding on a specific loss in response in milk yield, users are allowed to consider the trade off in milk versus functional traits from the perspective of their own situation. An iterative approach with different levels of non-market values was used to solve for the value that yielded maximum total selection response, while restricting selection response for ΔG_{NV} corresponding to *i*th percent loss.

RESULTS

Simultaneously derived non-market values for mastitis resistance and conception rate as a function of percent loss in selection response for milk yield are shown in Figure 1. Percentage loss in selection response for milk yield is the result of including non-market values for both mastitis resistance and conception rate relative to obtained selection response for milk yield with only market economic values. Selection response for milk yield with only market economic values (NV's for mastitis resistance and conception rate are zero) is 141.5 €.

With for example 5 and 10 percent loss in selection response in milk, non-market values are 42 and 75.6 € for mastitis resistance and 16.7 and 30.1 € for conception rate. These combinations of non-market values are the values, which maximize total selection response in the traits. Non-market values are higher for mastitis resistance than for conception rate. However, expressed as percent of market economic values, the increase in non-market values are the same for mastitis resistance and conception rate.

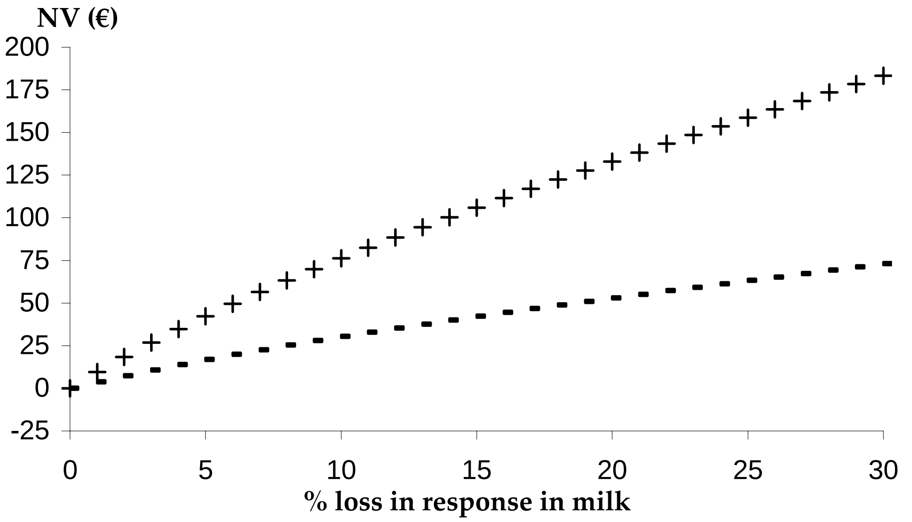

Figure 1. Non-market values (€/phenotypic standard deviation) for mastitis resistance (+) and conception rate (-) as a function of percent loss in selection response in milk.

Selection response for milk yield, mastitis resistance, conception rate and total selection response are given in Figure 2. It is seen that selection response for mastitis resistance becomes positive by about 7 percent loss in selection response in milk, whereas positive selection response for conception rate is not reached at a loss of 30 percent. The figure also shows that selection response for especially mastitis resistance can be significantly improved without a high reduction in total selection response. At 30 percent loss in response in milk, total response is reduced from 129.0 € to 113.9 € (11.7 %).

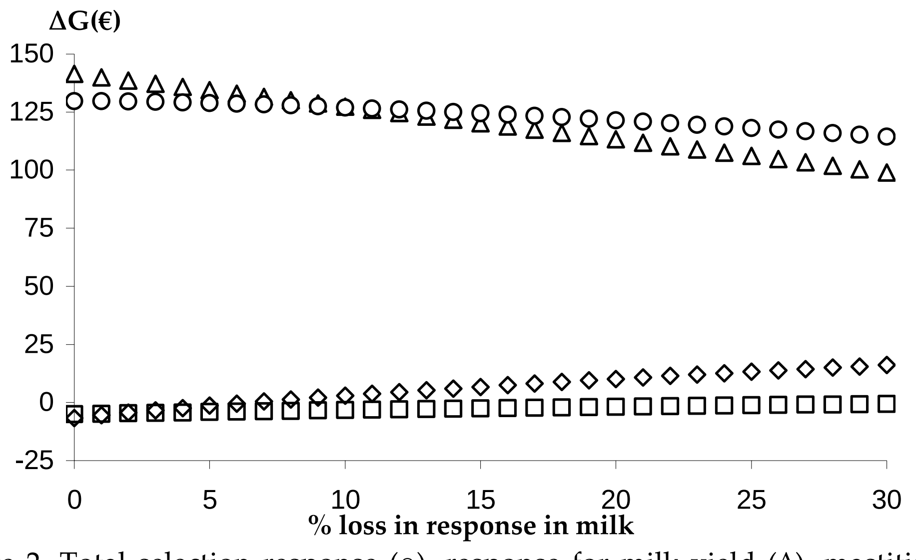

Figure 2. Total selection response (○), response for milk yield (Δ), mastitis resistance (◊) and conception rate (□) in €. Selection response for milk yield with zero loss (NV's for mastitis resistance and conception rate are zero) is 141.5 €.

DISCUSSION AND CONCLUSION

In this paper we presented a method to define sustainable breeding goals. The method was based on selection index theory and the trade-off between selection response for production and functional traits. It was demonstrated that the method could be used to derive non-market values in a breeding goal using an example from a dairy cattle breeding programme. In this study we extended the method by Nielsen et al. (2005) to allow for simultaneously derivation of non-market values for multiple traits. Non-market values were simultaneously derived for two functional traits (mastitis resistance and conception rate) with the loss in production (milk yield) distributed to each of the functional traits in order to maximise total selection response.

The results showed that non-market values were higher for mastitis resistance than for conception rate. However, the percentage increase was equal among the traits. Results also showed that the increase in selection response was higher for mastitis resistance than for conception rate. This was due to differences in heritabilities and market economic values, which were both highest for mastitis resistance. Positive selection response for mastitis resistance was obtained with only 7 percent loss in response in milk yield, whereas a much higher loss was required to obtain positive response for conception rate. These responses in mastitis resistance and conception rate yielded maximum total response. However, from a sustainable point of view it might be better to decide on a desired gain of mastitis and then distribute the loss to conception rate to get a more equal change in each of the traits.

The method was based on the trade-off between selection response for production versus functional traits. Most breeding companies, in particular breeding companies for dairy cattle, select animals based on total merit. Therefore one could argue that the method should be based on the trade-off between total selection response and response for functional traits instead of the trade-off between responses for production versus functional traits. However, since production usually is the main income of the farmer, they tend to look not only at total merit but also at performance of individual traits. Therefore, trade-of between production versus functional traits might appeal more to farmers than trade-off between total selection response versus responses in functional traits.

Olesen et al. (1999) revealed methods, which could possible be used to derive non-market values. These are among others desired gain indices and methods based on consumers willingness to pay for a given product. One of the disadvantages with the methods based on willingness to pay is that not all values can be derived in that way. One could imagine governmental legislation on welfare related traits. Consumers may not wish to pay for improved welfare, and the value of these welfare related traits can not be quantified using methods based on willingness to pay. Kanis et al. (2005) used so called retrospective selection indices to define sustainable breeding goals for pig breeding programmes. Their method is based on exploring the selection response surface for traits in the breeding goal by increasing the goal value for traits in the breeding goal, which are likely to have a non-market value. Based on the selection response surface, breeding company can then chose the goal values corresponding to the response, which they find most sustainable or acceptable.

Methods based on selection index theory have the advantage that they integrate the concept of sustainability into classical breeding methodology, which might appeal to farmers and breeding companies. It might also be easier to communicate with breeding companies based on selection response instead of economic values (Kanis et al. 2005), since the economic value in it self does not say much about the actual selection emphasis on a given trait. The method presented in this paper has the advantage that farmers or breeding companies can decide how much selection response they are willing to loose in a given production trait to improve functional traits. In addition, they can directly show the public how much response in production traits they are willing to loose to improve functional traits.

The resulting selection responses for the traits depend on assumptions about structure of the breeding plan and genetic, phenotypic and economic parameters. Besides increasing the goal value on functional traits, increased selection response could also be obtained by changing the structure of the breeding plan i.e. by increasing progeny group size. However, this is part of optimisation of the breeding plan, which should be performed based on the market economic value. To define sustainable breeding goals, selection response for the optimised breeding program should be predicted and non-market values should be added if predicted selection response is un-acceptable.

In this study we illustrated the method using an example from dairy cattle breeding with two functional traits only. However, the method can easily be extended to several functional traits as in most dairy cattle breeding goals. In addition, the method can be applied to other livestock species such as pigs, poultry and fish by changing the structure of the breeding plan. However, most breeding goals for poultry and fish are already based on desired gains indices not based on maximising economics. Therefore it is to be recommended that they derive market economic values based on profit equations or bio-economic models and then apply desired gain indices or other methods such as the one presented in the present paper to derive sustainable breeding goals.

In this paper we presented a method to define sustainable breeding goals based on the trade-off in response in production versus functional traits. It was shown that it is possible to improve functional traits by adding non-market values to the market economic values without high losses in total selection response. It is concluded that the method can be used to derive non-market values in order to define sustainable breeding goals.

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