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Derivation of Sustainable Breeding Goals for Dairy Cattle Using Selection Index Theory

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ABSTRACT

The objective was to present 2 methods for the derivation of nonmarket values for functional traits in dairy cattle using deterministic simulation and selection index theory. A nonmarket value can be a value representing animal welfare and societal influences for animal production, which can be added to market economic values in the breeding goal to define sustainable breeding goals. The first method was restricted indices. A consequence of adding a nonmarket value to a market economic value for a given functional trait is less selection emphasis on milk yield. In the second method, the loss in selection response in milk resulting from greater emphasis on functional traits was quantified. The 2 methods were demonstrated using a breeding goal for dairy cattle with 4 traits (milk yield, mastitis resistance, conception rate, and stillbirth). Nonmarket values derived separately using restricted indices were 0.4 and 2.6 times the value of market economic values for mastitis resistance and conception rate, respectively. Nonmarket values for mastitis resistance and conception rate were both lower when derived simultaneously than when derived separately. This was due to the positive genetic correlation between mastitis resistance and conception rate, and because both traits are negatively correlated with milk yield. Using the second method and accepting a 5% loss in selection response for milk yield, nonmarket values for mastitis, conception rate, and stillbirth were 0.3, 1.4, and 2.9 times the market economic values. It was concluded that the 2 methods could be used to derive nonmarket values for functional traits in dairy cattle.

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Abbreviation key: CONCR = conception rate, **EV** = market economic values, **MAST** = mastitis resistance, **MY** = milk yield, **NV** = nonmarket values, **SR** = selection response, **STB** = stillbirth.

INTRODUCTION

Breeding for dairy cattle worldwide has primarily focused on improving production traits. Selection for production traits only will lead to deterioration of functional traits (see review by Rauw et al., 1998), which is in conflict with animal welfare (Sandøe et al., 1999). Currently, however, the trend in dairy cattle is towards total merit indices and balanced breeding goals with explicit emphasis on functional traits (Mark, 2004). Even with a balanced breeding goal with emphasis on functional traits, deterioration of functional traits is not necessarily avoided (Christensen, 1998b).

Traditionally, economic values in the breeding goal are derived using profit equations (Brascamp et al., 1985; Dekkers and Gibson, 1998). When deriving economic values, the primary goal is to maximize farmer profit of the dairy cattle production system, which is based solely on the market economy (e.g., Groen, 1989). Due to increased public concern about animal health and welfare, it is also relevant to include social and ethical aspects of animal production when defining the breeding goal (Groen et al., 1997; Olesen et al., 2000). Sustainable livestock production can be defined as ecological production, which takes environment and biodiversity into account and is ethically and economically sustainable (Torp Donner and Juga, 1997). A sustainable breeding goal can be defined by weighing each trait in the breeding goal by a so-called nonmarket value (**NV**) and by traditionally derived economic values (market economic values, **EV**) (Olesen et al., 2000). The NV is a value to account for improved animal welfare and social aspects in the definition of the breeding goal.

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

Trait[1]	Milk yield	Mastitis resistance	Conception rate	Stillbirth	σ_P[2]	Market economic value
Milk yield	0.28	–0.35	–0.35	0	530	0.28
Mastitis resistance	0.03	0.04	0.20	0	1	163
Conception rate	–0.10	0	0.03	0	33	1.98
Stillbirth	0	0	0	0.04	24	–1.63

[1]Units: milk = kg/cow per yr; mastitis = incidence/cow per yr; conception rate and stillbirth = %/cow per yr; market economic value = €/unit per cow per yr.

[2]Phenotypic standard deviation.

Derivations of NV are complicated because these must be derived at the sector level with detailed modeling of the whole dairy cattle sector from producer to consumer. Alternatively, the sector level can be mimicked by evaluating the effect of including NV by sensitivity analysis using index calculations (Olesen et al., 2000). Even though tools for deriving NV have been proposed (Olesen et al., 1999), publications showing how to assign NV to dairy cattle traits are scarce.

The main objective of this study was to present 2 methods to derive NV using deterministic simulation and selection index theory. Initially, we applied principles by Olesen et al. (2000) to illustrate the effect on selection response of including NV in a breeding goal for dairy cattle containing milk yield, mastitis resistance, conception rate, and stillbirth. Desired gain indices can possibly be used to derive NV (Olesen et al., 1999). We tested this premise by deriving NV using restricted indices. A consequence of adding an NV to an EV for a given functional trait is less selection emphasis on milk yield. The second method was therefore based on the loss in selection response in milk by improving functional traits.

MATERIALS AND METHODS

Breeding Structure, Traits, Genetic, and Economic Parameters

For reasons of simplicity and because selection of dairy sires determines the largest amount of genetic gain, 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. The following 4 traits were included; milk yield (**MY**), mastitis resistance (**MAST**), conception rate (**CONCR**), and stillbirth (**STB**). Assumed heritabilities and genetic and phenotypic correlations (Table 1) were based on the review by Sørensen (1999). Market economic values were those reported by Nielsen (2004) representing the current Danish situation for dairy cattle.

Prediction of Selection Response

In this study, selection response (**SR**) was defined as genetic superiority of the selected bulls after one round of selection. Selection response for each trait was:

$$SR_T = \frac{\sigma_{IT}}{\sigma_I} \times i$$

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

Total selection response in monetary units (TSR) is the sum of selection response for all traits in the breeding goal valued by actual goal values for each trait (AGV_T) (Groen, 1990):

$$TSR = \sum_{i=1}^{T} AGV_T \times SR_T$$

Actual goal values are the values corresponding to the real situation at the moment of expression of selection response. Predicted goal values are those used in the breeding goal at the time of selection of the animals, which are included in the equation for selection response (SR_T). Correspondingly, the actual breeding goal is the breeding goal containing goal values corresponding to the realized situation at the time of expression of genetic improvement, whereas the predicted breeding goal is the goal on which the selection index and the selection of animals are based. Maximum selection response in monetary units is obtained when predicted circumstances equal actual production circumstances at the moment of expression of genetic improvement. If predicted and actual goal values differ, loss in economic revenue is observed (Groen, 1990).