AN APPROXIMATE TOTAL MERIT INDEX COMBINING LINEAR TRAITS, A SURVIVAL TRAIT AND A CATEGORICAL TRAIT IN LAYING HENS

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INTRODUCTION

In layer breeding programs, selection mainly focuses on number of eggs produced, feed efficiency and egg quality. Because of the global structure of the egg industry, primary breeding companies have to provide commercial layers that are able to express their full potential under a variety of field conditions such as high density cages, open houses, or free range systems. This implies, in addition to the above general selection criteria, intensified selection for livability and adaptability and reduced tendency toward feather pecking and cannibalism.

Livability is a compound trait, where each cause of mortality is a different trait (usually with very low incidence) and is highly dependent on environmental conditions. Under the controlled conditions of pure-line breeding farms, mortality is usually very low (<5%). Under commercial conditions, mortality can be higher because housing birds in multiple bird cages is stressful and can result in injuries. In such conditions, feather cover status can be used as an indicator of behavior characteristics : calm birds would have better feather cover.

To date, only egg production related traits described by linear models are included in multiple trait BLUP (MTBLUP) evaluations, and consequently, in total merit indices. For longevity and feather status, as well as other categorical traits, selection is based on independent culling levels. An approximate MTBLUP approach is presented here for the integration of these nonlinear traits in a total merit index. MTBLUP evaluations offer many theoretical advantages (van der Werf *et al*., 1992 ; Ducrocq, 1994). In particular, unbiased EBVs are available for all animals and all traits and the optional weighing factors in the total merit index are the economic weights for each trait, regardless of differences in EBV reliabilities.

MATERIAL AND METHODS

Population traits. In this data set, egg production traits were measured on 8700 pure-line laying hens placed in individual cages under a well-controlled environment. They were progeny of 114 cocks and 558 hens. These cocks also sired 5828 crossbred hens placed in multiple bird cages and recorded on longevity (LONG) defined as the number of days of life between housing and end of the production cycle, and feather cover status (FS) on a scale of 1 to 5 (well feathered to completely naked). Only the pedigree information on the sire's side was included.

Egg production traits were precocity or number of eggs laid between 19 and 25 weeks of age (PREC), persistency of lay or number of eggs laid between 40 and 60 weeks of age (PERS), and feed conversion ratio (FCR). PERS showed markedly skewed distribution, and was transformed using a Box-Cox transformation (Besbes *et al*., 1993).

General strategy. For linear and nonlinear traits, the current evaluation models include fixed effects and two random effects: an additive genetic effect and a full-sib effect. The proposed approach aims at summarising the data in such a way that the simplest (linear) animal model can be used for each trait. This implies first the calculation of a "pseudo-record" $y^*_{i,m}$ for each animal m and trait i, pre-adjusted for the fixed effects and for the full-sib effect. Then, all "pseudo-records" are analysed together using a classical MT-BLUP framework assuming an animal model:

$$y^*_{i,m} = \mu_i + a_{i,m} + e_{i,m} \qquad [1]$$

where μ_i is the overall mean for trait i, $a_{i,m}$ is the additive genetic value of animal m for trait i and $e_{i,m}$ is the residual. To account for the variable amount of information summarised in $y^*_{i,m}$, its residual variance is assumed to be heterogeneous: $\mathrm{var}(e_{i,m}) = \sigma^2_{e,i} / \omega_{i,m}$ where $\omega_{i,m}$ is the weight associated with "pseudo-record" $y^*_{i,m}$ and $\sigma^2_{e,i}$ is the reference residual variance for trait i. The derivation of "pseudo-records" and their weights were based on the following principle: when analysed using a *univariate* BLUP animal model evaluation, these records should lead to EBVs as close as possible to those obtained with the complete model and with the adequate methodology in the case of nonlinear traits. Then, the application of a MTBLUP animal model based on equation [1] is straightforward. It provides the appropriate EBVs for all traits and all animals. They are combined into the total merit index using a unique set of economic weights.

Calculation of "pseudo-records" and their associated weight For egg production traits, the evaluation was already a MTBLUP one. The model used was an animal model which included a hatch effect (e.g., h_l for animal m) and a full-sib effect: (e.g., c_f). The "pseudo-record" for trait i and animal m was simply the preadjusted record:

$$y^*_{i,m} = y_{i,m} - \hat{h}_l - \hat{c}_f \qquad [2]$$

The associated weight $\omega_{i,m}$ for the approximate MT-BLUP evaluation was the element of the coefficient matrix of the univariate evaluation obtained after absorption of the full-sib effect.

Longevity was analysed using a Weibull mixed model (see Ducrocq and Sölkner, 1998 ; Ducrocq *et al*., 2001). This model included the random effects of sire and full-sibs, and the fixed effects of the flock, the row in the battery where the cage was located, and the cage density at housing. To account for the decreasing density in the cage each time a death occurred, the model also included a time dependent density effect. Longevity "pseudo-records" and their weights were obtained using a two step procedure: the first step was the estimation of fixed effects and male EBVs using a sire-full-sib model. The second step consisted in calculating the hens' EBVs, considering fixed effects and male ancestors EBVs as known: an approximation of EBV solutions $\hat{a}_{j,m}$ from a Weibull animal model was obtained solving a non-linear equation for each animal m (Ducrocq, 2001). The resulting "pseudo-record" for longevity for animal m was:

$$y^*_{j,m} = \frac{\delta_m}{\omega_{i,m}} - e^{\hat{a}_{j,m}} + \hat{a}_{j,m} \qquad [3]$$

The associated weight $\omega_{i,m}$ was a function of the (possibly censored) length of productive life of hen m, her censoring code (δ_m = 0/1) and the fixed effects in the model. Calculations were done using the Survival Kit (Ducrocq and Sölkner, 1998). For details, see Ducrocq (2001).

Feather score was analysed using a threshold model which included the same effects as for longevity, except the time dependent density effect. Classically, the fixed and random effects estimates in threshold models are obtained iteratively solving systems of linear equations. At convergence, the equation of the last system to be solved can be rewritten, for each hen m, as:

$$\left[\omega_{k,m}\hat{a}_{k,m} + \frac{1}{\sigma^2_a}\left(\mathbf{A}^{-1}\hat{\mathbf{a}}_{\mathbf{k}}\right)_m\right] = \omega_{k,m}\, y^*_{k,m} \qquad [4]$$

where k refers to feather score, **A** is the relationship matrix, $\hat{\mathbf{a}}_{\mathbf{k}}$ is the vector of animal model solutions and $y^*_{k,m}$ the feather score pseudo-record for animal m which depends on thresholds, fixed and random effects solutions.

Joint analysis. Genetic and residual (co)variances were those obtained from previous analyses (Table 1), except for correlations between longevity, feather score on one hand and egg production traits on the other hand. These were estimated assuming a multivariate sire model, accounting for the nonlinear nature of the traits and using I. Misztal's Gibbs sampling package. Then a MT-BLUP evaluation based on "pseudo-records" (and their weights) was performed. Average reliabilities of males candidates to selection (Harris and Johnson, 1998) and selection differentials achieved on each trait were computed, considering here that selection is based on a hypothetical total merit index with equal economic weight for each genetic standard deviation of each trait.

RESULTS AND DISCUSSION

Validation. First, univariate analyses were performed based on "pseudo-records" for both longevity and feather score. The resulting EBVs were compared with the ones calculated from the appropriate models and methodology (survival analysis for longevity and threshold model for feather score). Results were encouraging : for longevity, the correlations between BLUP EBVs from "pseudo-records" and approximate Weibull animal model EBVs were 0.9997 for sires and 0.9988 for hens. For feather score, these correlations were 0.9931 and 0.9954, respectively.

Table 1. Heritabilities (diagonals), genetic correlations (upper triangle) and residual correlations (lower triangle) between the 5 traits considered in the approximate MT-BLUP animal model

Precocity	Persistency	Feed Conversion Ratio	Longevity	Feather score
0.40	-0.06	0.07	0.21	0.20
-0.02	**0.16**	0.14	0.16	-0.12
-0.02	0.05	**0.40**	0.31	0.34
0.00	0.00	0.00	**0.24**	0.16
0.00	0.00	0.00	0.15	**0.39**

Genetic correlations. Genetic correlations are reported on Table 1. They were lower than expected between longevity and feather score, but in the right direction: higher (worse) feather score leads to higher mortality. They were higher than anticipated between feed conversion ratio and the two functional traits: higher (worse) feed conversion ratio is associated with higher mortality and worse feather cover. These estimates need to be confirmed with other (or larger) data sets.

Joint evaluation. Average reliabilities for longevity were relatively low (0.29 for males candidates to selection) when only direct information on crossbred animals was used. Given the correlation between LONG and FS, the gain was only marginal when feather score was added (0.30) but more substantial (0.33 = +14%) when the five traits were analysed together.

Table 2. Selection differentials on the 5 traits when the selection is on a total merit index taking into account or not the correlation between linear and non linear traits

Total merit index	Precocity	Persistency	Feed Conversion Ratio	Longevity	Feather score
reference [A]	0.69	0.15	-0.49	-0.04	-0.32
approximate MTBLUP	0.50	0.17	-0.63	-0.06	-0.36

[A] with longevity and feather score treated univariately, ignoring correlations with other traits

Table 2 illustrates the change in selection differentials when a total merit index giving identical weight to all traits (in their favourable direction, i.e. for better precocity, better persistency, lower feed conversion ratio, less mortality, lower feather score) is applied with a selection intensity of 10%. A more favourable response is observed for all traits except for precocity.

CONCLUSION

The approximate MT-BLUP animal model proposed not only allows the combination of linear and non linear traits but also of crossbred and purebred performances considered as different traits (Wei and van der Werf, 1995). Admittedly, the approach still needs a careful and complete validation. It appears conceptually simple, general and flexible. Its application should lead to a more balanced progress on egg production, fitness and behavioral characteristics.

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