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Total merit index to estimate the breeding value of Polish arctic foxes*

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Reported are results of a 3-year study that attempted at introduction the BLUP AM and the total merit index (TMI) to Polish fur farming as tools for the estimation of breeding value with the use of the on-farm computer system. Presented is TMI proposed for the use in Polish arctic fox farming as well as the >FUTERKA< computer programme developed for collecting and organizing data, estimating breeding values and constructing the TMI.

KEY WORDS: arctic fox / computer system / total merit index

The breeding value of animals bred on farms is usually estimated using the mixed model method. Most often a mixed analysis of variance model is employed [Engel *et al.* 1999], referred to as an animal model (AM). The AM implies a unique type of analytical procedure that incorporates all sources of genetic information (all available records of animal's performance and performance of its relatives) into the prediction of breeding value, and in consequence high accuracy of predictors is achieved [Wright *et al.* 2000]. Identification of individuals with the highest genetic merit is a key point in achieving genetic progress. However, application of this procedure in the

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estimation of the breeding value of farmed fur animals has been delayed. Although for almost two decades major species of livestock have been selected on the basis of best linear unbiased predictions (BLUPs) of their breeding values [Robinson 1991], in fur farming the BLUP with an animal model was, for routine evaluation, introduced in Finland at the beginning of 1990s [Smëds 1992]. Since that time in Nordic countries, where this method is used [Sørensen *et al.* 2000, Hansen *et al.* 2000] considerable genetic improvement has been achieved.

Although in all modern breeding schemes, when selecting animals, the BLUPs of the breeding value are used, in Polish fur farming this method has not been applied. Instead of BLUPs, Polish fur farmers use, as selection criteria, the total score (sum of scores given for an animal during conformation and coat grading) or a simplified form of the selection index (calculated as a sum of scores given for four sources of information) – Wierzbicki and Filistowicz [2001]. These methods, however, are not reliable enough since subjectivity of grading and constructing the selection index without considering all available sources of information on animal genetic merit lead to the low accuracy of selection and finally result in the unsatisfactory genetic progress [Wierzbicki *et al.* 2000].

This paper reports on the results of a 3-year study on the introducing the BLUP AM and the total merit index (TMI) to the Polish fur farming as tools for the accurate breeding value estimation with the use of the on-farm computer system.

Materiał and methods

Animals

The study was carried out on the population of arctic fox (*Alopex lagopus*). The data on fur coat (n=5540) and reproductive performance (n = from 3080 to 5829 depending on the trait) were collected in the years 1983-1999. This population was considered as a model population for developing the scheme of estimation of breeding value in Polish fur farming. This means that after minor changes the scheme can be used for evaluating breeding value of other fur animals bred on farms. Detailed statistical description of the data used was given by Wierzbicki *et al.* [2004a].

Estimation of (co)variance components

The estimates of (co)variance components were obtained with the DFREML [Meyer 1998] and single- and multi-trait animal models. Due to a discrete character of fur coat traits, during the single-trait analysis they were analysed twice: (i) without normalization of their scores distribution, and (ii) after the norma1 probability scale transformation of their scores. Linear models included random additive genetic and common litter environment effects, fixed effect of year × birth season, and fixed effect of female age when the reproduction traits were analysed. Moreover, the variance components for fur coat traits were estimated under a linear model with or without inbreeding coefficients included as linear covariables. The pedigree structures, description of methods used (data transformation, linear models in matrix notation and assumptions) and results obtained were given in details by Wierzbicki [2004] and Wierzbicki and Jagusiak [2006].

Estimation of inbreeding depression risk

The inbreeding effect on the traits studied was estimated. As this study was carried out on the Polish and Finnish arctic fox population the risk of inbreeding depression was evaluated by comparing the results of the analyses carried out within Polish and Finnish fox populations. Statistical description of data, methods used and results obtained were presented by Wierzbicki *et al.* [2004b].

Derivation of economic weights

In order to select the traits to be included into the total merit index (TMI) the analysis was performed of factors affecting pelt prices in the international trading system (pelts are sold *via* auction houses in Europe). Based on this analysis the fur character traits were chosen affecting the monetary value of pelt to the highest degree. For these traits, then, the economic weights needed to construct the TMI were derived. The methods and data used when selecting the fur character traits to be included into the aggregate genotype as well as the results obtained were given by Wierzbicki [2005].

As an indicator of reproductive performance that should be included into the TMI chosen was the litter size at the age of 3 weeks. This trait reflects not only the fertility of animal, but also the nursing ability of the dam. The economic weight of this trait was also derived.

Further, a bio-economic model describing an integrated Polish fox farm was used to compute economic values for a number of traits related to productive life of arctic foxes. The model is deterministic and simulates yearly inputs and outputs of average Polish fox farm. The similar model has recently been developed in Finland and applied for computing the economic weights in Finnish blue fox production [Peura *et al.* 2004].

The model was used to estimate economic weights for direct (body size, fur quality, colour type) and maternal (litter size) traits. A 10-year investment period and two alternative discount rates of 0% and 6% were assumed when computing the number of discounted expressions (NDE). Marginal economic values (MEV) were calculated per one female purchased. Description of methods, input of biological and management parametres used for the estimation of economic weights and economic weights derived were given by Wierzbicki *et al.* [2005].

Total merit index (TMI) and computer system for data management and breeding value (BV) estimation

The final products coming from the arctic fox farming are pelts. The number, size and quality of pelts produced by a farm are crucial factors affecting its income. Thus, the selection criteria approved by the Central Animal Breeding Office [1999] are: body size (BS), colour type (CT), colour purity (CP) and fur quality (FQ). Furthermore, the litter size (LS) is usually used as a selection criterion when evaluating reproductive performance.

Because BLUP is not used in Polish fox farming the animals are selected based on the scores obtained during the grading of their phenotypes. In this type of selection the total score is the main criterion which expresses the value of aggregate genotype. No economic values of the traits included into the aggregate genotype are taken into account when calculating the total score.

In order the current method of estimation of breeding value be replaced with BLUP AM, the >FUTERKA< computer programme has been developed. The programme stores and organizes data collected on the farm, which are subsequently used for breeding value (BV) estimation and construction of TMI. Annual inflow of new information on animal productivity and reproductive performance updates the computer data base. This makes the annual re-estimation of BV of breeding animals possible, and improves the estimation accuracy.

Results and discussion

The simplified structure and functions of the >FUTERKA< computer system are illustrated by Figure 1. The programme consists of two modules. MODULE I is assigned for data collecting, updating and management, filling in the animal cards, calculating the farm statistics, and constructing the TMI, while MODULE II is for the BV estimation using the single trait BLUP AM. A decision to apply the single trait model has been made because (i) the estimated genetic correlations between fur coat traits showed high standard errors and (ii) the genetic correlations between litter size and skin traits could not be estimated since two different data sets were available: data on skin traits (1st set) which did not overlap data on reproductive performance (2nd set). Thus, genetic parametres were estimated using each of two data sets separately.

The MODULE I of the system has been developed to keep animal records up to date. Animal cards contain the most important information on individuals, e.g. animal number, cage number, pedigree information, birth date, grading results, reproduction results, breeder's remarks, TMI value, *etc*. The MODULE I computes farm' s simple statistics (trait means, number of breeding animals and pups within year, number of animals culled, pup mortality, *etc*.), and constructs TMI for animals. The data collected and organized are stored in the data file which is then used for BV estimation.

The >FUTERKA< computer programme estimates BVs using data collected on farm during grading (evaluation of body conformation and fur coat traits) and evaluation of reproductive performance. Indexes are calculated with the BLUP AM. The estimated breeding values (EBVs) are used for constructing TMI. The most important information on the estimation of BVs of traits included in TMI and their economic weights is given in Table 1.

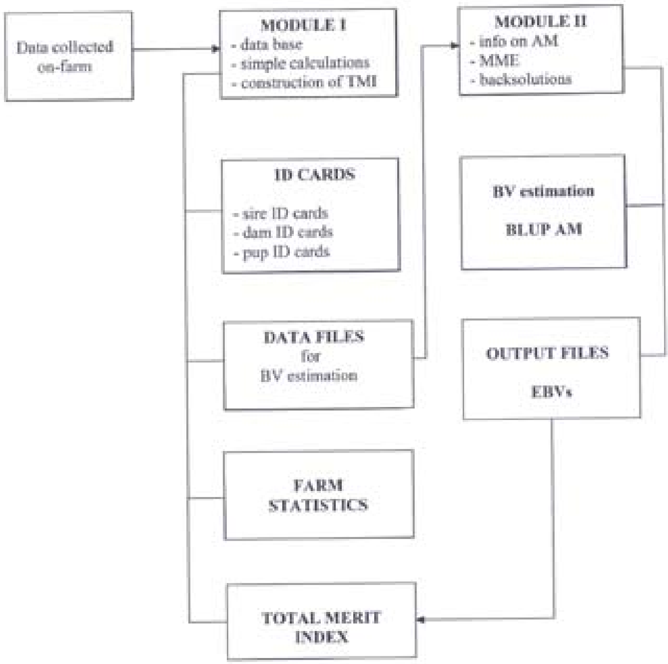

Fig. 1. Structure of the >FUTERKA< computer programme and its functions.

Table 1. Fixed and random effects in the animal model for estimation of breeding value, heritabilities and economic weight (EW) per genetic standard deviation [σ_a] of the traits included into TMI

	Effects included in the animal model						
	fixed			random			
Trait	year × birth season	farm × year × birth season*	female age	additive genetic	common litter environ-ment	h^2	EW per σ_a (PLN)
LS	+	+/-	+	+	+	0.205	3.494
BS	+	+/-	-	+	+	0.289	1.159
FQ	+	+/-	-	+	+	0.200	2.781
CT	+	+/-	-	+	+	0.325	0.193

*Can replace year × birth season if BV of animals originating from more than one farm is estimated.
LS – litter size; BS – body size; FQ – fur quality; CT – colour type.

The proposed TMI for Polish arctic fox production is as follows:

$$TMI = EW_{LS}\,EBV_{LS} + EW_{BS}\,EBV_{BS} + EW_{FQ}\,EBV_{FQ} + EW_{CT}\,EBV_{CT}$$

where: EW_{LS}, EW_{BS}, EW_{FQ} and EW_{CT} are economic weights for litter size, body size, fur quality and fur colour type, respectively; EBV_{LS}, EBV_{BS}, EBV_{FQ} and EBV_{CT} are estimated breeding values for litter size, body size, fur quality and colour type, respectively.

TMI constructed for Polish arctic fox farming should become the main criterion used for the selection of breeding animals. The index which takes into account production circumstances (through economic weights) is a reliable tool to change the genetic merit of animals so as they produce more products and of higher quality under present and future economic circumstances. The present TMI includes three production traits (concerning coat quality) and one reproduction trait (litter size). However, this TMI should be the first step on the way to construct more complex index taking into account functional traits (e.g. longevity, health and conformation) when evaluating an aggregate genotype. These traits increase production efficiency not through increasing output, but through reduced input costs. According to numerous authors [e.g. Linde and Philipsson 1998, Sölkner *et al.* 2000, Willam *et al.* 2002] the effect of not including functional traits in TMI results in 8-35% reduction in annual monetary genetic gain.

The present method of constructing TMI assumes the estimation of BV using a single trait model. However, unlike the variability of breeding objectives, estimation of breeding value for various traits finds common ground in almost all recording and evaluation schemes. This is a need to implement methods increasing the reliability of evaluation and to utilize all possible sources of information (genetic relationship and correlations) to increase selection accuracy and genetic gain [Philipsson *et al.* 1994]. Thus, further study should be focused on replacing the estimation of a single trait by multi-trait estimation. Moreover, the on-farm BV estimation should be replaced by the across-farms estimation in order to fully utilize all possible information sources (estimation of BV within one farm does not make use of genetic relations between individuals bred on different farms).

When discrete characters are evaluated the problem with analysis of non-normally distributed data appears. The fur coat traits are graded using a discrete scale and their distributions have heavier than normal tails. Thus, the normal probability scale transformation of the data was applied to test whether the transformation affects (co)variance components and EBVs. A comparison of estimates of heritability and portion of litter variation [Wierzbicki 2004] as well as genetic correlations [Wierzbicki and Jagusiak 2006] derived using data without transformation and probit-transformed ones revealed small differences between the estimates. Furthermore, no effect of data transformation on EBVs of fur coat traits was found. High positive Pearson's correlation coefficients ($P \leq 0.0001$) were computed between EBVs of fur coat traits estimated

Table 2. Pearson's correlation coefficients between EBVs computed using original and transformed data sets

Trait (n=5813)	Pearson's correlation coefficient
Body size	0.987**
Colour type	0.933**
Colour purity	0.995**
Coat density	0.934**
Hair length	0.997**
General appearance	0.987**
Total score	0.949**

**P≤0.0001.

using origina1 and transformed data sets (Tab. 2). Thus, the >FUTERKA< computer programme estimates BVs without transforming the data. No data transformation in order to normalize scores distribution is also applied both in Norway and Finland when estimating BVs for fur coat traits [Johannessen *et al.* 2000].

Using data without normal probability scale transformation reflects opinions of some other authors. According to Falconer and Mackay [1996] experimental observations should describe the genetic properties of the population, while a scale transformation obscures rather then illuminates the description. Moreover, according to Fernandez and Steel [1998] the existing toolbox for handling skewed and heavy-tailed data seems rather limited, the implementation of these approaches is complicated, and they lack flexibility and ease of interpretation.

Nordic countries, where the fox farming is well developed and organized (Norway and Finland) implemented TMI in the last decade [Smëds 1992, Johannessen *et al.* [2000]. However, the methods used for computing TMI were different in both countries.

In Norway, where the fur breeding plays a significant role in agriculture, high quality of pelts has been achieved by developing a system for live grading, using the SAS System for Information Delivery and a standard matrix index with full-sibs and half-sibs in the calculations. The data are recorded on farms and then sent to the central data bank for processing. After the statistical analyses BVs are estimated, combined selection index is calculated, and the results are sent back to the farmers. The system helps the farmer in grading and selection. Furthermore, it ensures that the BVs come into practical use, simultaneously affecting which animals are chosen as new breeding stock [Johannessen *et al*. 2000].

In Finland the transition from the phenotypic selection and the standard matrix index to BLUP AM took place at the beginning of 1990s [Smëds 1992]. Evaluation of breeding value is carried out on farms using the SAMPO computer software distributed by the Finnish Fur Breeders' Association. BV of economically important traits (evaluated traits are selected by breeders) is estimated using data collected on-farm (grading scores), data coming from skin auctions, or both sources of information are combined [Smëds 1992; Finnish Fur Breeders' Association – www.stk1-fpf.fi]. Mixed model equations relaxed the unrealistic assumption of the standard matrix selection index that the means for comparison are estimated without error.

The data presented can be summarized as follows. The transition from the phenotypic selection to BLUP AM and TMI as the selection criterion should increase the accuracy of selection and in consequence the efficiency of breeding schemes realized in Polish fur farming. Lack of recording systems to organize records of pertinent traits was a serious obstacle to introduce BLUP into practice. However, this constraint has been overcame by developing the >FUTERKA< computer programme to be used on-farm. This system collects and organizes data which are subsequently used for estimating breeding values and constructing TMI. Further studies and developments in computer programmes should concentrate on: (i) selecting the most important functional traits; (ii) estimating (co)variance components and computing economic weights for them; (iii) including functional traits into TMI; (iv) transition from the on-farm BV evaluation to across-farms BV evaluation; (v) replacing the single-trait evaluation by the multi-trait evaluation, and finally (vi) including results (scores) the final product of the fur farming-pelts receive during the international or domestic auctions into BV evaluation.

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Indeks łącznej wartości hodowlanej w polskiej hodowli lisa polarnego

S t r e s z c z e n i e

Przedstawiono wyniki badań zmierzających do wprowadzenia metody BLUP AM oraz indeksu łącznej wartości hodowlanej (TMI) do polskiej hodowli zwierząt futerkowych, jako narzędzi umożliwiających dokładne szacowanie wartości hodowlanej za pomocą fermowego systemu komputerowego. Opisano indeks TMI proponowany do wprowadzenia na polskich fermach lisa polarnego oraz komputerowy program >FUTERKA< opracowany dla gromadzenia danych i zarządzania nimi, szacowania wartości hodowlanych zwierząt oraz wyprowadzania indeksów TMI.