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An index to assist multiple trait selection of terminal beef sires in the UK

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ABSTRACT

A selection index which incorporates estimated breeding values of traits recorded in UK pedigree beef cattle breeds is described. The breeding objective is made up of growth and carcass traits, calving ease and gestation length.

The selection index is described in terms of the reduction in expected genetic response from selection on the index when individual recorded traits are omitted, the percentage contributions of recorded traits to variability in index scores, as well as the expected genetic responses in breeding objective traits with selection on the index. When all available traits have been recorded, calving traits explain approximately 30% of variability in index scores, with the remainder explained by growth and carcass traits.

The total index, along with two sub-indices for calving and production traits are scheduled to be implemented in Britain, along with the additional multi-trait estimates of animal breeding values required in 1997.

Keywords: beef cattle; selection index; terminal sire.

INTRODUCTION

Recent development and application of multi-trait animal model BLUP for genetic evaluation of beef cattle (Crump *et al.*, 1994), allows effective selection decisions to be made across the typically small, pedigree beef cattle breeding herds in the UK. However, there is a wide number of traits to be improved which, when presented individually, can be confusing to pedigree breeders as well as bull and semen buyers. The costs and returns associated with each trait are neither clear nor consistent through all sectors of the highly segmented beef production industry, so that there may not be appropriate incentives to breeders when applying emphasis to specific traits for improvement (Wilton, 1986).

A multi-trait selection index has previously been developed (Allen and Steane, 1985), to assist UK terminal sire buyers. Since then, carcass conformation and live animal muscling have become more important determinants of the value of finished animals in the industry, than was implied in the original index. There are also several new recorded traits, for which estimated breeding values will be available in the near future. Therefore, the objectives of this study were to develop a new selection index for terminal sire beef cattle in the UK which will be applied to multi-trait BLUP estimates of breeding values.

METHODS

Economic values for breeding objective traits

Models which give estimates of economic values for carcass weight, carcass fat score and carcass conformation score (Amer *et al.*, 1997), calving ease (Amer and Simm, 1997) and gestation length (Amer *et al.*, 1996) for the UK, have recently been developed. Economic values for carcass weight and carcass fat score were further adjusted for

anticipated correlated responses in feed intake, when feed intake is not recorded in the selection program, using the approach described by Amer and Emmans (1997). Economic values for traits in the index were taken as average values for the UK industry from the studies described above (Table 1).

Heritabilities for and correlations among recorded traits and breeding objective traits

The traits currently recorded and evaluated in the UK beef evaluation scheme and which are pertinent to terminal sire selection are 400 day weight, muscling score, ultrasonic subcutaneous fat depth, and birth weight (Crump *et al.*, 1994). New traits proposed for genetic evaluation in early 1997 include ultrasonic muscle depth, gestation length and calving ease.

Table 1 shows heritabilities and correlations for the recorded traits. The phenotypic correlations have no direct effect on the index but are required for calculations to describe the index. A majority of the parameters in Table 1 are based on Animal Model (AM) Residual Maximum Likelihood (REML) estimates from Mohiuddin (1994) and R. Crump (unpublished) using UK data and the review by Mohiuddin (1993) from international literature. Table 1 shows the genetic correlations between breeding objective traits and recorded traits used in the construction of the index. Correlations of growth, fat depth and muscling traits with carcass weight, carcass conformation score and carcass fat score were based on a review of international studies. Gestation length and calving ease are present both as recorded traits, and as breeding objective traits in the index, and correlations between them and other recorded traits were taken to be the same in the index as in the BLUP evaluations, under the assumption of no genotype by environment interactions. Correlations for 400 day weight, muscling score, muscle depth and fat depth with gestation

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TABLE 1: Heritabilities (diagonal and bold), genetic (above diagonal), phenotypic correlations (below diagonal) and genetic standard deviations and economic values assumed in the index

Objective traits ¹	Recorded traits								
	400 day weight	Muscling score	Muscle depth	Fat depth	Birth weight	Gestation length	Calving ease	Economic value	Genetic standard deviation
Carcass weight	.6	.3	.3	.1	.15	.1	-.1	£1.2 /kg	12.5 kg
Carcass conformation score ²	.2	.6	.6	.1	.15	.1	-.1	£7 /unit	1.04 units
Carcass fat score ²	.1	0	.1	.4	0	0	0	£-6 /unit	.73 units
Gestation length	.3	.2	.2	0	.4	1.0	-.5	£1 /day	3.2 days
Calving ease ³	-.3	-.2	-.2	0	-.5	-.5	1.0	£7.6 / σ_p	.39 σ_p
Recorded traits									
400 day weight	.4	.55	.55	.12	.41	.3	-.3		
Muscling score	.44	.26	.65	.0	.39	.2	-.2		
Muscle depth	.43	.49	.26	.18	.47	.2	-.2		
Fat depth	.22	.12	.16	.29	.09	0	0		
Birth weight	.19	.1	.1	.05	.24	.4	-.5		
Gestation length	.3	.2	.2	0	.24	.4	-.5		
Calving ease	-.3	-.2	-.2	0	-.35	0	.15		
Genetic sd	39.5 kg	1.2 units	.53 mm	.52 mm	3.5 kg	3.2 days	.39 σ_p		

¹ Note all correlations between objective traits and recorded traits are genetic correlations

² Carcass conformation score and carcass fat score are expressed on a 15 unit scale. See Kempster et al (1986) for the relationship between the units and the EUROP carcass grading scores used commercially in the UK.

³ Calving ease is expressed on an underlying standard normal phenotypic scale, so the units for this trait are phenotypic standard deviations on the underlying scale.

length and calving ease were assumed, taking into account differences in farm management between pedigree and commercial farms.

Genetic standard deviations

Genetic standard deviations for carcass weight, carcass conformation score and carcass fat score (Table 1) were estimated from crossbred progeny of pedigree bulls out of commercial suckler cows. The genetic standard deviation for gestation length was assumed to be 3.2 days based on estimates from literature. For calving ease evaluated on an underlying standard normal scale (phenotypic variance equals 1), the genetic standard deviation was taken as the square root of the heritability. Genetic standard deviations for other recorded traits were supplied by R. Crump (personal communication). However, when the index is applied in practice, breed specific estimates of phenotypic variances will be incorporated into the index formulation as part of the overall genetic evaluation computer programs.

Theory for index construction

Let G be an n by n genetic variance-covariance matrix for n recorded traits and C be an m by n genetic covariance matrix between m non-recorded, breeding objective traits and the recorded traits. Genetic variances and covariances are calculated from trait heritabilities, phenotypic variances and genetic correlations.

A vector of estimated breeding values for breeding objective traits (\hat{u}_p) for each animal can be computed from breeding values for recorded traits (\hat{u}_r) as $\hat{u}_p = CG^{-1}\hat{u}_r$. Now let v be a vector of dimension m of economic values for unit changes in each breeding objective trait. With multi-

trait BLUP evaluations, the optimal ranking index (I) for each animal would be obtained from $I = v' CG^{-1}\hat{u}_r$ (Schneeberger *et al.*, 1992). Now let P be an n by n phenotypic variance covariance matrix. The variance of the index is $\sigma_I^2 = b' Pb$ where $b = P^{-1}C'v$.

Description of indexes

While genetic selection indexes are constructed in terms of population parameters (genetic variances and correlations) and economic weighting factors, it is more convenient to view each index in terms of selection response in, and the relative importance of, individual traits. Multi-trait BLUP includes information on all recorded relatives so that accuracies of evaluation can be different for every individual. To facilitate the computation of selection response and contribution of individual traits to the index we have assumed that the information available for selection is equivalent to 1 phenotypic record per trait on each animal to be considered for selection (mass selection). The proportion of variance (Pr_i) accounted for by EBV trait i in the index can then be computed as follows (Amer and Simm, 1997);

$$Pr_i = \frac{1}{\sigma_I^2} \sum_{j=1}^n \frac{k_{i,i}}{k_{i,i} + k_{j,j}} 2k_{i,j}$$

where $k_{ij} = b_i P_{ij} b_j$. Under mass selection, responses in each profit trait can be calculated using $R_j = i(b'C_j) / b'Pb$ where i is the selection intensity and C_j is the j th column of matrix C . Finally, the value of each recorded trait in the index was calculated as the reduction in overall selection response when that trait was dropped from the full index and from reduced indexes (Cunningham, 1970).

Sub-indexes

It is possible to define sub-indexes, for which some of the breeding objective traits are assigned economic values of zero. Two sub-indexes were considered in this study. The first, from now on referred to as the calving index, corresponds to the total index described above, but with economic values for carcass weight, carcass conformation score and carcass fat score assigned values of zero. The second index, from now on referred to as the production index, corresponds to the total index, but with economic values for calving ease and gestation length assigned values of zero.

RESULTS

Table 2 shows the expected reduction in economic response to selection when individual traits are omitted from either the full selection index (assuming information is available on individuals for all traits) and for four reduced indexes. Reduced indexes have been considered because often breeders are unable to, or choose not to, record some traits. For example, breeders using natural mating do not have gestation length records. Scanning traits are not always measured because of the associated expense. Weight at 400 days followed by gestation length and then calving ease appear to be the most critical recorded traits in the total index when considered on an individual basis. However, birth weight increases in value to the index when gestation length and calving ease are not recorded. Muscling score is also more important when muscle depth and fat depth are not recorded.

TABLE 2: The proportional reduction in response to selection on the index for the full index and for four reduced indexes where alternative combinations of traits have not been recorded.

Individual recorded traits removed from indices	Full index	Traits not recorded			
		Calving ease	Calving ease and gestation length	All calving traits ¹	Scanning traits ²
400 day weight	.25	.23	.22	.22	.31
Muscling score	.03	.03	.04	.03	.09
Muscle depth	.03	.04	.04	.02	-
Fat depth	.02	.02	.01	.02	-
Birth weight	.02	.03	.11	-	.07
Gestation length	.12	.14	-	-	.08
Calving ease	.07	-	-	-	.01

¹ Calving traits are calving ease, gestation length and birth weight.
² Scanning traits are ultrasonic fat depth and ultrasonic muscle depth.

Table 3 shows the proportional contributions of individual recorded traits to variability in the index with alternative combinations of recorded traits. Weight at 400 days controls between approximately .5 and .7 of index variability across the alternatives considered, increasing with decreasing numbers of calving traits recorded. Muscling score, muscle depth, calving ease and gestation length all have moderate effects on index variability.

Expected economic responses from selecting on the alternative indexes are shown in Table 4. With selection

TABLE 3: The proportional contribution of individual recorded traits to variability in the index for the full index and for four reduced indexes where alternative combinations of traits have not been recorded.

Individual recorded traits removed from indices	Full index	Traits not recorded			
		Calving ease	Calving ease and gestation length	All calving traits ¹	Scanning traits ²
400 day weight	.51	.57	.68	.77	.56
Muscling score	.08	.11	.15	.13	.15
Muscle depth	.08	.12	.17	.08	-
Fat depth	.03	.03	.02	.02	-
Production sub-index	.70	.83	1.02	1.00	.71
Birth weight	.04	.03	-.02	-	.12
Gestation length	.15	.14	-	-	.15
Calving ease	.11	-	-	-	.02
Calving sub-index	.30	.17	-.02	-	.29

¹ Calving traits are calving ease, gestation length and birth weight.
² Scanning traits are ultrasonic fat depth and ultrasonic muscle depth.

TABLE 4: Expected economic superiority (£) over the average bull of progeny from the top 40% of bulls ranked for the full index and for four reduced indexes where alternative combinations of traits have not been recorded.

Breeding objective trait	Full index	Traits not recorded			
		Calving ease	Calving ease and gestation length	All calving traits ¹	Scanning traits ²
Carcass weight	2.48	2.45	2.58	2.59	2.27
Carcass conformation score	.79	.83	.95	.86	.78
Carcass fat score	-.05	-.06	-.06	-.04	-.12
Gestation length	.37	.28	-.18	-.31	.15
Calving ease	.24	.06	-.13	-.28	-.06
Total	3.82	3.56	3.17	2.83	3.42

¹ Calving traits are calving ease, gestation length and birth weight.
² Scanning traits are ultrasonic fat depth and ultrasonic muscle depth.

on the total index, all traits move in a favorable direction except carcass fat score. However, in the absence of scanning traits in the index, this unfavorable change more than doubles. The responses in calving ease and gestation length are also unfavorable if neither of these traits is recorded, although when birth weight is recorded, the size of unfavorable changes in these traits is approximately halved.

Index sensitivity to errors in parameters

A sensitivity analysis (methods and results not presented) revealed that the index is robust to errors in economic values and genetic standard deviations. Carcass weight requires the most accurate genetic correlations with measured traits. However, these parameters have been specified for the index with a relatively high degree of confidence. Uncertainty in the true values for the genetic correlations for carcass conformation with muscle score and muscle depth, combined with moderate sensitivity of the index to errors in them, means that obtaining

more accurate estimates of these correlations should be a priority for future research.

DISCUSSION

The index described was designed for the specific purpose of assisting buyers to select the best (most profitable) terminal sires when making bull and semen purchase decisions. Although this was also the purpose of the index developed by Allen and Steane (1985), their index is largely driven by the ability of 200 and 400 day weights, fat depth and muscling score to predict saleable meat yield and feed intake. It also makes some allowance for calving ease, although in practice, the effect of a reduction in birth weight on calving ease is offset by the relatively high correlation between birth weight and the other weights, so that very little variability in index scores can be attributed to birth weight.

The disadvantages of specifying part of the breeding objective in terms of saleable meat yield have been discussed by Amer *et al.* (1997). Relative weights of recorded traits depend largely on their correlations with saleable meat yield. However, commercial carcass price differentials have consistently placed much greater emphasis on carcass conformation, and much less emphasis on carcass fat than implied by the correlations with saleable meat yield used in the existing index. Industry confidence in the index has been eroded, at least partly because of this inconsistency.

Artificial insemination accounts for a substantial proportion of pedigree cow matings in the UK and therefore gestation length is a potential new selection criterion for UK beef cattle. Gestation length, which tends to be quite highly heritable, is important both through its correlation with calving ease, and also because it increases the effective length of the breeding season of suckler and dairy cows carrying calves for shorter periods of gestation (Amer *et al.* 1996). Calving ease is also of high economic importance although it appears slightly less important in the index, probably because it has a lower heritability and less genetic variation. In practice, calving ease may make even less of a contribution, because of problems with recording in extensively managed pedigree herds, and an additional problem with uninformative records (all animals having the same calving ease score) with small contemporary groups.

Related studies have shown that economic values for calving ease (Amer and Simm, 1997), gestation length (Amer *et al.* 1996), carcass fat score and carcass conformation score (Amer *et al.* 1997) are expected to vary substantially across farms. One approach to deal with this is to provide a system of customising indexes to meet the needs of individuals or small groups of users (Barwick *et al.* 1994). Most indexes (Smith, 1983), including the present one, are robust to moderate to large errors or changes in economic weights, and so theoretical benefits from customising indexes are expected to be small (Visscher and Amer, 1996). However, index users are often quick to detect discrepancies between generalised breeding objec-

tives and their own circumstances, which perhaps unjustly, erodes confidence in the value of the index.

A major role of this terminal sire beef index is to provide an independent and simplified basis for purchasers of beef bulls and semen to make optimal buying decisions. Under a system of customised indexes, it would be much harder for this role to be maintained. As an alternative to customised indexes, two sub indexes, for calving traits and for production traits, will be published in addition to the total index. These sub-indexes allow interested parties to make their own trade-offs between calving and slaughter traits.

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