Optimisation of progeny testing schemes when functional traits play an important role in the total merit index

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Abstract

It is expected that the inclusion of functional traits in the total merit index has some consequences on the design of progeny testing schemes in dairy cattle. Functional traits are usually traits with low heritability and more daughters per sire seem necessary to provide enough information about the breeding values for those traits. A complex deterministic model (computer program ZPLAN) is used to describe the breeding programme of the Austrian Brown Swiss cattle population. The total merit index includes the dairy traits fat and protein yield and the functional traits longevity, fertility, somatic cell score, persistency, calving ease and stillbirth. The relative economic weights of dairy vs. functional traits (calculated as sum of weights of individual traits scaled to genetic standard deviations) are 45 vs. 55 percent. To find the optimum breeding scheme, proportion of cows inseminated with test bulls and the number of test bulls are varied. To evaluate the effect of inclusion of functional traits on the testing scheme, optimisation is performed for selection on an index including only dairy traits and on a total merit index including dairy and functional traits. Criteria for the evaluation of different schemes are annual monetary genetic gain and discounted profit accounting for variation of costs under different testing schemes. Under the circumstances of the Austrian Brown Swiss population selection for total merit index basically needs the same design as selection for milk traits only. Although the economic weight of the functional traits is high, the contribution of functional traits to total merit is rather small, probably due to the low heritabilities of the functional traits and the high correlation between fat and protein yields. If functional traits are not considered in the index, the expected changes in most of these traits are negative.

1. Introduction

The design of a progeny testing scheme affects the rate of genetic improvement in the population and also the costs of the program. Most of the costs are associated with the number of bulls tested annually. For the Austrian Brown Swiss population simulation studies are carried out to optimise the progeny testing scheme under selection for total merit index. The Brown Swiss population consists out of 82,320 cows in total, where 88% are registered in the herd book. Thirty percent of all inseminations are done with semen mainly from the USA and partly from Germany and Italy. Presently the test capacity is 30 percent and in average 45 progeny records per test bull are obtained.

Under the circumstances of decreasing producer revenues for milk, it is desirable that the production costs are as low as possible. Therefore traits such as longevity, somatic cell count, calving ease etc. seem advisable to be included in the breeding goal. The Austrian Brown Swiss Association has defined a total merit index with 45% of the economic weight (scaled to genetic standard deviations) on milk traits and 55 % on functional traits as their main breeding objective.

For the milk traits a sufficient reliability of the breeding values is obtained already with the present number of progeny. Due to the low heritability of the functional traits and the important role of functional traits in the total merit index it seems necessary to increase the number of progeny for improvement of the accuracy of the breeding values.

The objectives of this paper are to address how progeny testing schemes should be changed in order to maximise annual monetary genetic gain and discounted profit by selection for total merit index with a high value of functional traits.

2. Breeding structure

The essential input parameters used to describe the present situation are based on an evaluation of the Austrian Brown Swiss breeding programme:

Population parameters	
Population size	
Proportion of recorded cows	
Proportion of AI	0.82
No. of young bulls tested per year	50
No. of proven bulls selected per year within population	10
No. of proven bulls selected per year from abroad	15
No. of proven bulls for mating with bull dams	3
No. of proven bulls from abroad for mating with bull dams	6
Proportion of insemination with foreign bulls in total	0.30
Inseminations per lactation record	15
No. of selected bull dams per year	1,206
Average number of cows per farm	8.7
Biological coefficients	
Av. time period between calving (years)	1.13
Number of inseminations per pregnancy	2
Stillbirth rate	0.04
Losses during raising (female)	0.10
Losses during raising (male)	0.25
Use of proven bulls (years)	2
Use of proven bulls for mating with bull dams (years)	1
Use of bull dams (year)	2
Use of dams (years)	4.4
Mean generation interval in years (all selection groups)	5.74
Cost parameters (EUR)	
Milk recording costs per cow	22.7
Inspection bull dam per selected bull dam	66
Inspection calf per selected calf	12.5
Station test per young bull	757
Herdbook registration per cow	11
Production costs per semen dose	1.23
Storage costs per semen dose	0.05
Variable costs per test bull	3,044
Interest rates calculating returns and costs	0.06; 0.04
Investment period (years)	20

The costs are average costs based on calculations by the breeding organisations and artificial insemination centres. The milk recording costs and the system of semen policy are the major costs involved.

From each test bull 10,000 doses of semen are taken. Those not used for test inseminations are stored and the bulls are culled. The variable costs per test bull consist of incentives paid to farmers for progeny records and costs associated with the description of conformation traits.

3. Method

3.1. ZPLAN

The program ZPLAN (Karras *et al.*, 1994) was used to describe the Austrian Brown Swiss breeding program. It is designed to optimise selection strategies in livestock breeding by a pure deterministic approach. The gene flow method and selection index procedures constitute the core of the program. It is evaluating both the genetic and economic efficiency of breeding strategies. The user has to define all selection groups in the whole population, each with specific selection intensity and other particular information sources used in the index. The program calculates a number of criteria such as annual monetary genetic gain for the aggregate genotype, annual genetic gain for single traits, discounted return and discounted profit for a given time period.

The criteria to evaluate alternative breeding programs used in this study are defined as follows:

Annual monetary genetic gain (AMGG): Monetary superiority (per year) of progeny of the selected animals of one selection round in the breeding unit.

Discounted returns (R): Cumulated discounted returns per cow in the whole population (breeding and commercial unit) within investment period based on the genetic superiority of the selected animals of one selection round.

Discounted profit (P): Discounted profit per cow (discounted returns minus discounted breeding costs).

3.2. Selection index

The total merit index for the Austrian Brown Swiss as defined in Miesenberger (1997) and Miesenberger *et al.* (1998) is used and includes 11 traits (2 dairy and 9 functional traits). Heritabilities, genotypic and phenotypic correlations and economic values were mainly taken from Miesenberger (1997) and derived from literature. The genetic standard deviations and the economic weights per additive genetic standard deviation of single traits is shown in Table 1. The matrix of heritabilities, phenotypic and genetic correlations used in the total meritindex is given in Table 2.

Table 1. **Genetic standard deviation (s_A) and economic weights (in EUR) per genetic standard deviation of the traits in the total merit index**

Trait	Abbreviation	Unit	s_A	Economic weight
Fat yield	Fat	Kg	14.8	26.94
Protein yield	Protein	Kg	9.8	27.73
Longevity	Long.	Day	180	27
Persistency	Pers	s_A	1	4.36
Fertility paternal	Fer-p	%	5	8
Fertility maternal	Fer-m	%	5	8
Calving ease paternal	Ce-p	Class	0.22	1.07
Calving ease maternal	Ce-m	Class	0.22	1.07
Stillbirth paternal	Sb-p	%	2.5	3.45
Stillbirth maternal	Sb-m	%	2.5	3.45
Somatic cell count	SCC	s_A	1	14.53

Table 2. Phenotypic (upper triangle), genetic (lower triangle) correlations and heritablities (diagonal elements) of the traits in the total merit index

	Trait	1	2	3	4	5	6	7	8	9	10	11
1	Fat	**0.30**	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Protein	0.85	**0.28**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Long.	-0.10	-0.10	**0.10**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Pers	0.00	0.00	0.20	**0.15**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Fer-p	-0.10	-0.10	0.10	0.20	**0.02**	0.00	0.00	0.00	0.00	0.00	0.00
6	Fer-m	-0.20	-0.20	0.10	0.20	0.00	**0.02**	0.00	0.00	0.00	0.15	0.00
7	Ce-p	-0.10	-0.10	0.0	0.00	0.00	0.00	**0.05**	0.00	0.15	0.00	0.00
8	Ce-m	0.10	0.10	0.15	0.00	0.00	0.00	-0.10	**0.05**	0.00	0.00	0.00
9	Sb-p	0.00	0.00	0.0	0.00	0.00	0.00	0.80	0.00	**0.05**	0.00	0.00
10	Sb-m	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.80	-0.10	**0.05**	0.00
11	SCC	-0.25	-0.25	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	**0.14**

3.3. Variation of test capacity and number of test bulls

The effect of variation in test capacity and number of test bulls is studied for selection on the total merit index as defined above and for selection on milk traits only. The model for milk traits includes fat and protein yield, economic weights of all the functional traits are assumed to be zero and only information on milk traits is considered in this index.

The proportion of test inseminations presently carried out in the Austrian Brown Swiss population is 30 percent; 50 test bulls are sampled every year. For analyses of the progeny-testing program the test capacity and the number of test bulls were varied. The test capacity was varied between 20 and 70 percent. Within each test capacity the number of test bulls was reduced to 40, 30 and 20 young bulls and increased to 60 and 70 bulls per year. Because of limited space only variations with 30, 50 and 70 test bulls are presented in the tables.

With increasing number of young bulls more bull dams are used and selection intensity for bull dams decreases. On the other hand the selection intensity for the proven bulls increases with increasing number of test bulls. The variation of test capacity only has no effect on the selection intensities for the test bulls, proven bulls and bull dams. Change in the number of test bulls and in the test capacity has an effect on the progeny group size (progeny per test bull are indicated under P/TB in the tables).

4. Results and discussion

The annual genetic gain for index traits (in genetic standard deviations) with selection on TMI and dairy traits only are listed in Table 3. As expected the gain for fat and protein yield is higher for selection on dairy traits only. In reality the functional traits have an economic weight. If the gain for each trait is multiplied with the economic weight the total annual monetary gain for TMI is 9.58 EUR whereas based on the index for dairy traits it is 8.48 EUR (i.e. 1.1 EUR less) because of the negative contributions of the functional traits.

The effects of variation in test capacity and the number of test bulls are in Table 4. They show the impact on the annual monetary genetic gain for all traits when selecting on the total merit index (TMI) and for dairy traits only when selecting for an index on dairy traits (D). All the calculations are compared with the present structure (50 test bulls and testing capacity of 0.3, in bold). It would be expected that more progeny information increases the accuracy of the breeding values and the AMGG. But the change in test capacity influences several components and some of them are moving AMGG in opposite directions.

Table 3. **Annual genetic gain (genetic standard deviations) when selecting for total merit index (TMI) or dairy traits only (D) for the base situation**

Trait	TMI	D
Fat yield	0.1636	0.1879
Protein yield	0.1621	0.1860
Longevity	0.0337	-0.0199
Persistency	0.0314	0.0000
Fertility paternal	-0.0078	-0.0199
Fertility maternal	-0.0201	-0.0398
Calving ease paternal	-0.0191	-0.0199
Calving ease maternal	0.0420	0.0199
Stillbirth paternal	0.0003	0.0000
Stillbirth maternal	0.0218	0.0000
Somatic cell count	-0.0171	-0.0498

Table 4. **Effect of test capacity (TC) and number of test bulls (TB) on annual monetary genetic gain (AMGG) for selection on total merit index (TMI) and dairy traits (D). P/TB is number of lactating daughters per test bull (a result of the set of TB and TC imposed)**

	TMI						D					
	TB=30	P/TB	TB=50	P/TB	TB=70	P/TB	TS=30	P/TB	TB=50	P/TB	TB=70	P/TB
TC=0.2	9.46	52	9.51	31	9.45	22	10.14	52	10.20	31	10.14	22
TC=0.3	9.53	79	9.58	47	9.51	33	10.17	79	10.23	47	10.18	33
TC=0.4	9.55	105	9.58	63	9.52	45	10.16	105	10.21	63	10.17	45
TC=0.5	9.55	132	9.55	79	9.48	56	10.14	132	10.16	79	10.11	56
TC=0.6	9.53	158	9.50	95	9.41	67	10.11	158	10.10	95	10.02	67
TC=0.7	9.51	184	9.43	110	9.32	79	10.07	184	10.01	110	9.93	79

The optimum is located at test capacity of 0.3 to 0.4 and 50 bulls. Reduction of the number of test bulls increases the amount of information, the selection intensity of the bull dams, but on the other hand decreases the selection intensity for proven bulls. The decrease is implied by the increase of genes from test bulls with higher test capacity. This has the positive effect of a shorter mean generation interval, but a higher importance of test bull selection groups which means less realisation of proven bulls. All the changes are very small and show a strong robustness of the system.

The absolute level of AMGG under selection on milk traits (neglecting the negative response in functional traits) is 0.64 EUR higher than selection on TMI. The optimum is almost the same as for TMI. The reduction with increasing test capacity is higher than for TMI. This could be due to the fact that increasing number of progeny contribute to the AMGG for TMI and decrease the reduction compared to selection for milk traits only. In general the loss in the selection intensity on the side of the proven bulls is outweighing the gain of information.

For a trait with heritability of 0.25 Dekkers *et al.* (1996) found similiar results. The rate of genetic gain was maximised with progeny groups between 57 and 61 daughters, but was relatively insensitive to changes in the size of the progeny group.

Table 5. **Effect of increasing test capacity (TC) and the number of test bulls on discounted profit for selection on total merit index (TMI) and dairy traits (D)**

	TMI						D					
	TB=30	P/TB	TB=50	P/TB	TB=70	P/TB	TS=30	P/TB	TB=50	P/TB	TB=70	P/TB
TC=0.2	2.18	52	0.15	31	-3.04	22	2.59	52	0.59	31	-2.60	22
TC=0.3	2.85	79	0.81	47	-2.40	33	3.12	79	1.12	47	-2.04	33
TC=0.4	3.34	105	1.18	63	-2.03	45	3.49	105	1.39	63	-1.77	45
TC=0.5	3.75	132	1.39	79	-1.92	56	3.81	132	1.51	79	-1.74	56
TC=0.6	4.08	158	1.50	95	-1.93	67	4.06	158	1.55	95	-1.80	67
TC=0.7	4.37	184	1.52	110	-2.02	79	4.30	184	1.54	110	-1.92	79

Table 6. **Effect of increasing test capacity (TC) and the number of test bulls on the genetic gain for longevity for selection on total merit index (TMI) and dairy traits (D)**

	TMI						D					
	TB=30	P/TB	TB=50	P/TB	TB=70	P/TB	TS=30	P/TB	TB=50	P/TB	TB=70	P/TB
TC=0.2	0.0329	52	0.0322	31	0.0311	22	-0.0198	52	-0.0198	31	-0.0197	22
TC=0.3	0.0344	79	0.0337	47	0.0325	33	-0.0198	79	-0.0199	47	-0.0198	33
TC=0.4	0.0354	105	0.0346	63	0.0335	45	-0.0198	105	-0.0199	63	-0.0198	45
TC=0.5	0.0361	132	0.0351	79	0.0338	56	-0.0198	132	-0.0198	79	-0.0197	56
TC=0.6	0.0364	158	0.0352	95	0.0339	67	-0.0197	158	-0.0197	95	-0.0195	67
TC=0.7	0.0366	184	0.0351	110	0.0337	79	-0.0197	184	-0.0195	110	-0.0194	79

The discounted profit is calculated as discounted return minus the discounted breeding cost. The profit shows a picture that is different from the AMGG. Under the present cost structure the realised profit is very low (0.8 EUR for TMI and 1.12 EUR for D). It is observed that the profit is very much dependent on the number of test bulls. The problem would look differently, if the proportion of the breeding unit in comparison to the total population would be smaller as all the costs are related to the total population. Then the milk recording costs, which are the major costs per cow, would be less in this case.

From a strict economic point of view 20 test bulls and a test capacity of 0.7 is the optimum for the total merit index as well as for the dairy trait index. It has to be noted here that inbreeding is not considered in the deterministic approach of ZPLAN. Changes in the semen policy might help to improve the profit.

The discounted profit is related to the total population and to the planning horizon of 20 years whereas the monetary genetic gain is based only on the breeding unit and one year. Higher test capacities result in earlier realisations.

With increase of the test capacity the discounted return (not shown here) is increasing till 50 percent test capacity depending on the number of test bulls. The optimum is located for TMI at 50 young bulls and test capacity of 0.6 with 95 progeny records. For dairy traits only the optimum is located at 60 bulls, test capacity of 0.5 and 66 progeny records.

Table 6 shows that the inclusion of functional traits in the TMI helps to achieve a positive trend for longevity, whereas selection for dairy traits only results in a decrease of longevity. For all the other functional traits either a positive natural genetic gain could be reached or at least the negative trend could be stopped. The same trends are found by Wegmann (1996).

The results in Table 6 indicate very clearly that with increasing the number of information for the breeding value estimation, the natural genetic gain for longevity is rising. More success is achieved by increase of the test capacity than by the reduction of the number of bulls. With selection on dairy traits only, changes in the number of progeny do not affect the natural genetic gain for longevity.

When selecting for TMI, the total contribution of functional traits to AMGG (not shown) varies from 4.0 to 8.9 percent. The minimum refers to 70 bulls and a test capacity of 0.2 , the maximum to 20 bulls and a test capacity of 0.7 . In the present situation the functional traits contribute 7.1 percent to AMGG.

Heckenberger (1991) analysed the contribution of functional traits to the AMGG in dependence on the size of the population, test capacity and number of progeny. He found similiar trends, although a bit lower.

5. Conclusions

Under the circumstances of the Austrian Brown Swiss population selection on a total merit index basically demands the same design of the progeny-testing scheme as selection on dairy traits only. Although the relative economic weight of dairy vs. functional traits is 45 vs. 55 percent, the contribution of functional traits it rather small due to the low heritabilities of these traits and the high correlation between fat and protein yield. If selection is on dairy traits only, a negative development in the complex of the functional traits is expected.

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