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Heritability of lifetime milk yield and productive life and their relationship with production and type traits in the Simmental, Swiss Fleckvieh and Red Holstein populations in Switzerland

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Abstract

Costs of milk production can be reduced through lower replacement rate by increasing productive life of cows. Lifetime production (LP, production to 6th lactation) and productive life (PL, number of completed lactations) of 112,850 daughters of 766 test AI bulls were used to obtain daughter averages and to estimate heritabilities. Bulls belonged to three sections of the Swiss Simmental and Red&White cattle herd book, differing in percentage of Red Holstein genes. Correlations of daughter average LP and PL with sire EBVs for production, functional and type traits and with composite indices differed among herd book sections and, in some instances, changed signs (e.g., for correlations with EBV for linearly scored muscling) due to different breeding objectives. The strongest correlations of LP were found with EBV milk (>0.69), of PL with total merit index (0.44 to 0.52) and the composite fitness index (0.32 to 0.56). Heritabilities were estimated using two sire models (without or with including a fixed effect of herd book section). They were around 0.19 and 0.13 for LP, and 0.111 and 0.097 for PL from the two models. Estimates obtained from the first model may be more appropriate because breeding objectives differ among herd book sections.

Introduction

Reducing the average replacement rate by increasing productive life of cows is one of the options to reduce costs of milk production in dairy herds. Ducrocq and Soelkner (1998) reported estimated heritabilities of longevity between 0.05 and 0.1, obtained using a conventional linear model, and values between 0.15 and 0.2 when a Weibull proportional hazard model was employed, corresponding with the estimate of 0.18 by Caraviello et al. (2004). Several studies (Caraviello et al., 2002; Weigel et al., 2002; Cruickshank et al., 2002; Hare et al., 2006; Abdallah et al., 2002; Sewalem et al., 2004; Tsuruta et al., 2005; Vukasinovic et al., 2002) reported correlations between type traits and longevity. The strongest correlations were found with udder traits (suspension of fore and hind udder, udder depth, central ligament) and traits of feet, legs and claws.

The purpose of this study was to investigate factors affecting lifetime milk production and productive life, estimating the heritability of these traits, as well as their relationship with production, functional and type traits in the Simmental, Swiss Fleckvieh and Red Holstein populations.

Material and methods

The dataset used in this investigation included records of 112,850 daughters of 766 test AI bulls, born between 1985 and 1993. Only bulls with at least 50 daughters, and only daughters from the testing period were considered. Table 1 summarises the performance of the cows, and Table 2 shows the distribution of the bulls on three sections of the Swiss Simmental and Red&White cattle herd book, i.e., Simmental (with a maximum of 13 % Red Holstein genes, SI), Swiss Fleckvieh (13 to 74 % Red Holstein, SF) and Red Holstein (≥ 75 % Red Holstein, RH), together with their average number of daughters from the testing period, average daughters' life time milk production up to sixth lactation, average percentage of daughters with ≥ 6 lactations, and average culling rate of daughters in first lactation.

Table 1: Summary of the performances of all cows.

Trait	Number of cows	Average	Standard deviation	Minimum	Maximum
Milk kg up to 6th lactation	112,530	15,770	13,295	7	80,687
Fat kg up to 6th lactation	112,517	509.3	429.4	1	2,504
Protein kg up to 6th lactation	112,519	650.0	549.1	1	3,475
Number of lactations	112,674	3.096	2.256	1	16

Table 2: Distribution of bulls on herdbook sections and daughter averages.

Section of Herdbook (see text)	Number of bulls	Average number of daughters	Average milk production of daughters up to 6th lactation (kg)	Average percentage of daughters with ≥ 6 lactations (%)	Average culling rate from 1st to 2nd lactation (%)
SI	200	124	11`464	14.3	37.9
SF	307	143	14`810	15.4	32.9
RH	259	172	19`002	15.9	29.7
Total	766	148	15`341	15.3	32.9

Lifetime production (LP) was defined as production up to 6th lactation (limited to 6th lactation because some of the daughters of the youngest bulls included in the analysis were still alive at the time of this investigation), productive life (PL) as number of completed lactations. Correlations between sire means of LP and PL and sire estimated breeding values for production, functional and type traits, as well as selected composite estimated breeding values (indices) were calculated. These correlations, however, are neither pure genetic nor phenotypic measures, but may, nevertheless, give some indication on the relationships among the investigated traits.

Heritabilities for LP (milk, fat and protein) and PL were estimated by a linear sire model. A fixed environmental effect was defined as the combination of two regional classifications (geographical region and altitude) and herd production level. The random sire effect was modelled in two alternative ways, nested or not nested within fixed herd book section.

Results

The average culling rate from first to second lactation of daughters of all bulls was 32.9 %, with the highest value (27.9 %) for SI and the lowest (29.7 %) for RH bulls, whereas the value found for SF bulls corresponded to the overall average (Table 2). Looking at the percentage of daughters producing during ≥ 6 lactations, the SF were again near the overall mean, the SI bulls had the lowest and the RH bulls the highest percentage. Average milk LP of daughters was highest for RH (19,002 kg) and almost 8,000 kg lower for SI bulls, reflecting the inferior milk production potential and the higher culling rate of daughters of SI bulls.

Table 3 gives correlations by herd book section between the daughter means of milk LP and PL with estimated breeding values of production and functional traits, as well as composite indices.

Table 4 reports correlations by herd book section of LP and PL with EBV for type traits. These include scores for the four positions body conformation, feet and legs, udder and teats, as well as overall score; measured height at withers; and selected linear type traits.

Table 3: Correlations between daughter means of milk production of daughters to 6th lactation (LP) and number of lactations (PL) with estimated breeding values (EBV) of production and functional traits and composite indices for bulls belonging to three herd book sections.

Herd book section (see text)	RH		SF		SI	
	LP	PL	LP	PL	LP	PL
EBV milk kg	0.692	0.244	0.759	0.423	0.694	0.452
EBV fat %	-0.351	-0.214	-0.153	-0.059	-0.159	-0.131
EBV Protein %	-0.326	-0.177	-0.307	-0.154	-0.223	-0.155
EBV somatic cell count (SCC)	-0.021	0.288	0.079	0.214	-0.035	0.149
EBV persistency	-0.225	-0.005	-0.189	-0.089	-0.262	-0.137
ILM (composite index milk) [1)]	0.432	0.087	0.497	0.307	0.480	0.373
IME (composite index type traits) [2)]	0.348	0.34	0.178	0.243	0.153	0.147
IVF (composite index meat production) [3)]			-0.200	-0.298	0.362	0.429
IFI (composite index fitness) [4)]	0.213	0.558	0.238	0.442	0.095	0.324
Total merit index [5)]	0.601	0.452	0.505	0.437	0.637	0.520

[1)] Index combining EBVs for milk kg, fat and protein kg and %.
[2)] Index combining EBVs for linear type traits.
[3)] Index combining EBVs for growth and carcass conformation (not given for RH bulls).
[4)] Index combining EBVs for SCC, productive life, persistency,reproduction (Non Return Rate and time to first service), production increase from first to later lactations, milkability and dystocia.
[5)] Index combining ILM, IME, IVF and IFI.

Table 4: Correlations between daughter means of milk production of daughters to 6th lactation (LP) and number of lactations (PL) with estimated breeding values (EBV) of type traits for bulls belonging to three herd book sections.

	RH		SF		SI	
	LP	PL	LP	PL	LP	PL
Score for body conformation	0.205	0.174	-0.037	0.043	-0.005	0.011
Score for feet and legs	0.188	0.255	0.125	0.210	-0.008	-0.042
Score for udder	0.070	0.198	0.218	0.229	0.256	0.280
Score for teats	0.284	0.369	0.349	0.315	0.193	0.171
Overall score	0.252	0.327	0.168	0.244	0.148	0.155
Height at withers (cm)	0.102	-0.046	0.096	0.153	-0.038	-0.067
Linear type traits:						
Width	0.003	0.075	-0.186	-0.161	-0.252	-0.233
Muscling	0.172	0.291	-0.304	-0.058	-0.251	-0.11
Hooks	-0.045	-0.035	0.256	0.185	0.128	0.028
Rear legs	0.218	0.215	-0.038	-0.003	-0.068	-0.072
Fore udder	0.094	0.099	0.415	0.319	0.200	0.166
Rear udder	0.036	0.014	0.101	-0.075	0.309	0.183
Udder depth	0.070	0.213	0.100	0.260	0.007	0.099
Udder quality	0.072	0.209	0.164	0.238	0.209	0.309
Teat shape	-0.098	-0.086	-0.161	-0.214	-0.192	-0.299
Teat length	-0.279	-0.336	-0.273	-0.254	-0.298	-0.305

Table 5 summarizes the estimated heritabilities for LP and PL. The estimates were lower when the herd book section of the sires was included as a fixed effect in the linear model and the random sire effect was modelled nested within this fixed effect. The heritability estimates for LP were almost 0.2 using the model without nesting sires within section and around 0.13 for the model with the nested effects. Heritability estimates for PL were around 0.1 and, thus, in the range of other fitness traits.

Table 5: Estimated heritabilities of milk production to 6th lactation (LP) and number of lactations (PL) with models taking or not taking into account herd book section of sires .

	Including herd book section of sire	
Trait	no	yes
LP milk kg	0.195	0.138
LP fat kg	0.192	0.129
LP protein kg	0.182	0.134
PL	0.111	0.097

Discussion

EBVs for milk of bulls are positively correlated (> 0.6) with daughters' average LP in all herd book sections (Table 3). Cows producing high milk yield often reach high LP, but in fewer lactations than low producing cows. This is reflected in the lower correlations of EBV milk with average PL (0.24 to 0.45). The same tendency is observed in the correlations of LP and PL with the composite index for milk production (ILM). Correlations of ILM with LP were 0.4 to 0.5, with PL 0.09, 0.31 and 0.37 for RH, SF and SI bulls resp. The largest difference between the correlations of EBV milk or ILM with LP and with PL was found for RH bulls. The reason could be higher culling due to insufficient milk production of daughters of SF and particularly SI sires than of daughters of RH sires. EBVs for fat and protein % were negatively correlated with both daughter averages, being in line with the generally negative relationship between milk yield and content.

The fitness index (IFI) was positively correlated with the daughter average for LP (0.21 and 0.24 for RH and SF bulls, but only 0.1 for SI bulls). A more pronounced correlation of IFI was found with PL (0.32 for SI, 0.44 for SF, and 0.56 for RH bulls). This strong correlation is due to the high weight for the EBV for productive life in the IFI, the weight being 50% in the IFI for RH bulls. Only weak correlations (-0.035 to +0.079) were found between EBV for SCC and daughter average LP, but were between +0.15 and +0.29 with PL. It has to be noted that EBVs for SCC are published as relative EBVs with high values indicating desirable EBVs, i.e. low SCC. The EBV for persistency, also a component of IFI, was negatively correlated with average LP and, to a lesser extent, with PL. The different signs (negative for SF, positive for SI) observed for the correlations between the index for meat production (IFV) and average LP and PL reflect the different breeding objectives for the two herd book sections (IFV is not given for RH bulls).

Positive relationships were obtained between the composite type index (IME) and LP and PL for all herd book sections with the strongest values for RH bulls. The total merit index, combining the above indices, and placing most weight on the milk production index, was again positively correlated with both, LP and PL. The different magnitudes of the correlations in the three herd book sections, again, reflect different breeding objectives and, thus, different index weights in the individual herd book sections.

The results for the correlations of daughter average LP and PL with EBVs for type traits (Table 4) reveal variation between herd book section, possibly reflecting different breeding objectives, with most uniform results obtained for correlations with EBVs for teat characteristics. Daughters of sires with EBV for long teats reach lower LP and PL, which is probably due to more intensive voluntary culling for this trait. While Cruickshank et al. (2002) reported a negative relationship between stature and functional herd life in US Guernseys, the correlations from this study between EBV for height at withers were near zero with PL and LP, ex-

cept for correlations >0.1 between EBV for height at withers with LP in RH bulls and PL in SF bulls.

An interesting conclusion may be drawn from the difference of the correlations between EBV for muscling and average LP and PL. They are positive for RH, but negative for SF and SI bulls. Swiss Simmental and Red&White cattle breeders seem to favour some, but not too much, muscling and, thus, tend to cull daughters of RH bulls with low muscling EBV to select against too little, and daughters of SF and SI bulls with high muscling EBV to select against too much muscling.

The heritability of LP is moderate and somewhat lower than heritability estimates usually reported for lactation production (Table 5). This indicates that selection on this trait could be successful, but would lead to an increased generation interval. The high correlation of average daughter LP with EBV milk indicate, however, that selection on lactation milk yield also tends to improve LP.

The heritability estimates for PL of around 0.1 correspond with results reported in the literature (Ducrocq and Soelkner, 1998). The positive correlations between average daughter PL and EBV for productive life or IFI lead to the conclusion that these measures, routinely available to breeders, provide a good opportunity for improving longevity.

The heritability estimates obtained from the statistical model with nesting sire effects within fixed effects of herd book section may be more appropriate, given the fact, demonstrated in various cases in this analysis, that breeding objectives differ in the various herd book sections.

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