Relationship between longevity and selected production, reproduction and type traits

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ABSTRACT: The correlations between longevity, functional longevity, stayability and selected milk, reproductive and type traits were estimated; it was done on the basis of estimated breeding values for longevity, functional longevity, dairy traits, reproductive traits and stayability rates at the age of 60, 72, 84, and 96 months. The correlation between breeding values for longevity and functional longevity was 0.69. The correlations between longevity and stayability at 60, 72, 84, and 96 months of age were around 0.75 (from 0.73 to 0.76) whereas the correlation with stayability at 48 months was considerably lower (0.64). The breeding values for dairy traits showed a positive relationship with longevity (from 0.37 to 0.46) and a slightly negative correlation with breeding values for functional longevity (from –0.10 to –0.20). A low relationship was found between longevity and reproductive traits. Between the type traits and longevity traits only the conformation score for the form (0.18) and for the udder showed a positive correlation (0.24). The correlation between the form and functional longevity remained approximately on the same level whereas the correlation with the main udder score decreased to 0.08, which indicated a positive relationship between milk traits and udder scores.

Keywords: cattle; longevity; functional longevity; milk traits; reproduction traits; type traits

Longevity of cows is an important component of profits from milk production because high longevity reduces rearing costs and enables the animals to reach their age dependent maximum of milk production. Robertson and Barker (1966) derived the following reasons of this effect (higher longevity) on the economics of dairy production:

1. A lower number of heifers have to be reared or selection intensity can be increased.
2. More cows reach their age dependent maximum in milk production.

Many investigations showed the economic importance of longevity in dairy cows (Dekkers *et al.*, 1994; Dürr *et al.*, 1999; Weigel *et al.*, 2003).

The impact of BSE caused an unexpected culling of older cows in the last period. This can relate directly or indirectly to estimation of cattle longevity. The survival analysis of censored data makes it possible to get a meaningful result for genetic conclusions about one year earlier than by analysing the stayability data.

Rensing *et al.* (2002) described the new Total Merit Index RZG for Holstein in Germany. Longevity became the second important trait complex in RZG with 25% for RZN (relative breeding value for functional herd life) contrary to 6% in the past. Direct functional life, evaluated by the Survival Kit, is combined with the breeding values of auxiliary traits (SCS, body depth, feet & legs score, fore udder attachment and maternal calving ease).

VanRaden and Sanders (2003) analysed heterosis and breed differences in milk yield traits, somatic cell score and productive life as a measure of longevity. Crossbred and purebred dairy cattle were estimated on the basis of heterosis economic merit.

Ducrocq (1992) distinguished between two types of longevity: (real) longevity that can be observed directly and is strongly dependent upon the milk

Supported by the Science and Technology Assistance Agency (Project No. 20-006702) and the Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences (Project No. 1/0604/03).

yield, and functional longevity that is the ability of the cow to avoid culling for other reasons than low performance. From a genetic point of view the functional longevity seems to be more important because it is a trait measuring vitality and reproductive performance.

The aim of selection of the functional traits is to reduce the level of involuntary culling of high-producing cows. In expanded dairy herds Weigel *et al.* (2003) described the relative risk of voluntary culling of low-producing cows and involuntary culling of high-producing cows on the basis of Weibull model for survival analysis.

Sölkner and Petschina (1999) analysed the relationship of various type traits obtained from a linear scoring system with the length of productive life of dairy cows of the Austrian Simmental breed. Out of the 24 type traits, 12 showed a significant positive linear effect. The highest positive effect was found for udder score.

Bouška *et al.* (1999) described the relations between the conformation of Czech Pied first-calvers and their production characteristics. A significant positive relationship was observed between percentage of protein and body capacity (r_g = 0.37) and muscularity (r_g = 0.32).

The whole genome scan for functional traits was performed in the German Holstein cattle population. Loci with the influence on udder traits and/or udder health may also contribute to genetic variance of longevity (Kühn *et al.*, 2003).

MATERIAL AND METHODS

Official sire genetic evaluation of the Bavarian Simmental population (from 1995) for longevity (EBV for longevity and functional longevity), stayability rates at the age of 48, 60, 72 and 84 months (relative values), milk traits (Index MZW, EBV for milk, fat, protein and breeding values separately for the parts of the first lactation and breeding values for the second and third lactation), reproductive traits (EBV for maternal and paternal non-return rate, calving ease and stillbirth) and for type traits (relative values for main traits: size, muscularity, form and udder, 8 detailed form traits and 5 detailed udder traits) were used for estimating the correlations.

Götz and Luntz (2003) described the breeding value estimations for Bavarian Simmental cattle in Germany.

The selection of bulls for progeny testing was done on the basis of dairy traits and birth dates (1980 to 1987). The main reason to use only the older sire evaluation was to exclude the BSE impact on the genetic evaluation of cattle longevity. Sire evaluations were available for 3 381 bulls (longevity), 3 269 bulls (milk traits), 3 361 bulls (non-return rate), 3 372 bulls (calving ease and stillbirth) and only 1 599 bulls with type traits evaluations.

The estimation procedure for functional longevity from Egger-Danner (1993) was used for the analyses. The Hazar-function λ (t, z_i, str) used for the breeding value estimation for animal j at time t is as follows:

$$\lambda (t, z_i, \text{str}) = \lambda_{0_{\text{str}}}(t) \times \exp(\sum_{r=1}^{2}\beta_{1r}(X_{1i} - x_1)^r + \sum_{r=1}^{2}\beta_{2r}(X_{2i} - x_2)^r + s_j)$$

where:
- $\lambda_{0_{\text{str}}}(t)$ = baseline-Hazard-function stratified in subgroups with average longevity of contemporary comparisons within region and similar age at first calving
- X_{1i} = relative milk yield of cow i within herd
- X_{2i} = Relative fat percentage of cow i within herd
- β_{1r}, β_{2r} = linear (r = 1) or quadratic (r = 2) regression coefficients for X_{1i} and X_{2i}
- x_1, x_2 = means of the strata of the covariates X_{1i} and X_{2i}
- s_j = random effect of the sire

The same estimation procedure for longevity without relative milk yield and relative fat percentage effects was used for the estimation of breeding values.

A sire model was used for estimating breeding values accounting for the relationship between sires on the paths of their sires and maternal grandsires. The culling risk based on the length of productive life was used as independent variable. The culling risk of the daughters of a sire can be estimated by regression coefficients. Negative regression coefficients indicate a lower risk for culling and therefore a higher length of productive life. The older results of bulls could be reported to avoid bias because of the low incidence of culled daughters for progenies of younger bulls. The official genetic evaluation (animal model) was used for breeding values of milk traits and reproductive traits. Stayability rates and type traits were used from sire evaluation as relative values.

RESULTS AND DISCUSSION

The available longevity traits (stayability rates at 48, 60, 72 and 84 months of age) and estimated breeding values (EBV) for longevity and functional longevity showed positive correlations with each other (Table 1). The correlation between longevity and functional longevity was 0.69. Philpot *et al.* (1997) published high genetic correlations between true herd life and functional herd life for Quebec Holstein, ranging from 0.74 to 0.98, which is typical of Holstein cows in general. The correlation between longevity and stayability showed a significant increase from stayability 48 months to stayability 72 months, whereas from 60 months the correlation with longevity increased only slightly. The reduced value of stayability 48 for the selection purposes was obtained. Since the risk for culling increases with low milk production, the correlations between stayability and functional longevity are markedly lower. But the increase in the correlation from stayability 48 to stayability 60 also occurs with functional longevity.

Comparable correlations in the Simmental population according to stayability rates (0.57–0.90) (Averdunk and Georgoudis, 1985) correspond with our results.

The correlations between breeding values for longevity and dairy traits were around 0.40 (Table 2). Only fat and protein percentage had a low or a slightly negative correlation with longevity. Animal Model, which has been applied in Germany since 1990, divides the first lactation into three parts. Therefore correlations with longevity can be calculated for each part of the first lactation. Within the first lactation the correlation for the first 100 days with longevity is lower than for the second or third 100 days (Table 3). This indicated that better persistency within the first lactation reduced the risk of culling.

The breeding values for functional longevity showed negative correlations with all breeding values for selected milk traits. The correlations were in the range from –0.10 to –0.23. This means that with an increasing genetic level for dairy traits the risk of culling for other reasons than low milk production also increased. A higher performance in dairy traits may result in problems in other traits, e.g. fertility, which can lead to a higher culling rate. In the Holstein populations these correlations are often around zero, when a country uses functional longevity contrary to countries using true longevity. Correlations between milk yields and longevity ranged from 0.53 to –0.29 according to the countries that input international longevity evaluations (Powell and Van Raden, 2003). Sölkner *et al.* (1999) also published negative correlations between longevity and fat and protein for Simmental and Brown Swiss population. Differences between populations can be due to different culling strategies in dairy and dual-purpose cattle and due to the existence or absence of quota systems.

The breeding values for fertility (non-return rate), stillbirth and calving ease, which are subdivided into a paternal and a maternal component, showed low correlations with longevity. The correlations with the maternal component were higher than with the paternal component (Table 4). This holds especially for fertility and calving ease, where the paternal component seems to be negligible and the maternal component is quite apparent. The correlation between fertility and functional longevity (0.20) was much higher than with longevity. Equivalent correlations were estimated by Sölkner *et al.* (1999) on the basis of traits in the total merit index for the Austrian Simmental population. They

Table 1. Correlations between estimated breeding values for longevity and stayability rates

Trait	*n*	Longevity (EBV)	Functional longevity (EBV)
Longevity (EBV)	3 381	–	0.69***
Functional longevity (EBV)	3 381	0.69***	–
Stayability: 48 months	3 106	0.64***	0.38***
60 months	2 712	0.73***	0.45***
72 months	2 308	0.76***	0.49***
84 months	1 910	0.73***	0.49***

***$P < 0.001$

Table 2. Correlations between estimated breeding values for longevity and milk traits (n = 3 269)

Trait	Longevity (EBV)	Functional longevity (EBV)
Index (MZW)	0.39***	–0.23***
Milk – kg (EBV)	0.41***	–0.15***
Fat – kg (EBV)	0.37***	–0.21***
Protein – kg (EBV)	0.37***	–0.22***
Fat – % (EBV)	0.005***	–0.11***
Protein – % (EBV)	–0.037***	–0.10***

***P < 0.001

Table 3. Correlations between estimated breeding values for longevity and milk traits (according to lactation and parts of the first lactation) (n = 3 269)

Trait Milk – kg (EBV)	Longevity (EBV)	Functional longevity (EBV)
1–100 days	0.34***	–0.15***
101–200 days	0.39***	–0.14***
201–300 days	0.40***	–0.11***
Second lactation	0.40***	–0.14***
Third lactation	0.39***	–0.15***

***P < 0.001, NS – not significant

indicated that high-producing cows had a lower culling risk due to fertility problems. The maternal components of calving ease and stillbirth do not show higher correlations with functional longevity. Therefore the culling strategy seems to be independent of milk production.

Only the main type traits: form and udder and some of their single components had an influence on longevity or functional longevity (Table 5). Whereas the main form score had a correlation of 0.18 with longevity and functional longevity too, the main udder score had a much higher correlation with longevity than with functional longevity (0.24 versus 0.11). All form components showed no difference between the correlations with longevity and functional longevity. Udder components showed lower correlations with functional longevity than with longevity. For front udder and rear udder, which gave information about the size of the udder, the correlation decreased to zero if the functional longevity was used. This indicates that the advantage of those animals in longevity was based on higher milk production. The remaining single udder traits showed reduced correlations with functional longevity, which means that this influence can be divided into a milk dependent and milk independent part.

CONCLUSIONS

Stayability rates should not be used before the age of 60 months, which is too late for conventional dairy breeding programmes

The correlations with other evaluated traits show the influence of dairy traits, some type traits, fertility traits and calving ease on longevity. The correlations were reduced for some traits if functional longevity was analysed

These observed correlations may be time dependent and should therefore be verified in defined intervals (when the genetic base is changed)

Table 4. Correlations between estimated breeding values for longevity and reproductive traits (n = 3 361)

Trait		Longevity (EBV)	Functional longevity (EBV)
NRR90	maternal (EBV)	0.09***	0.20***
	paternal (EBV)	0.004***	0.02^{NS}
Calving ease	maternal (EBV)	0.14***	0.16***
	paternal (EBV)	0.05***	0.04***
Stillbirth	maternal (EBV)	0.09***	0.11***
	paternal (EBV)	0.07***	0.09***

***P < 0.001, NS – not significant

Table 5. Correlations between estimated breeding values for longevity and type traits (n = 1 599)

Trait	Longevity (EBV)	Functional longevity (EBV)
Size	0.004^{NS}	0.05**
Muscularity	–0.06**	0.08**
Form	0.18***	0.18***
Udder	0.24***	0.11***
Form traits		
Shoulder	0.07*	0.08**
Back	0.03***	0.09***
Rump angle	0.10*	0.08***
Angularity of join I	0.14***	0.13***
Angularity of join II	0.12***	0.09**
Ankle	0.16***	0.16***
Hoof angle	0.05**	0.07**
Spreading of claws	0.12***	0.11***
Udder traits		
Front udder	0.17***	0.02^{NS}
Rear udder	0.17***	–0.01^{NS}
Udder attachment	0.19***	0.12***
Teat development	0.19***	0.09***
Teat placement	0.15***	0.09***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, NS – not significant

Acknowledgements

The cooperation of the Bavarian State Institute of Animal Production in Grub for providing data during the sabbatical opportunity of the first author.

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Received: 03–09–11
Accepted after corrections: 04–11–16

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