Relationships between longevity and conformation traits in Czech Fleckvieh cows

L. Zavadilová, E. Němcová, M. Štípková, J. Bouška

Institute of Animal Science, Prague-Uhříněves, Czech Republic

ABSTRACT: The relationships between conformation and longevity traits were analysed in 58 493 Czech Fleckvieh cows first calved from 1994 to 2003. All cows were scored for conformation during the first lactation. Genetic correlations between longevity and conformation traits were estimated by bivariate runs using the VCE 4.0 program for variance component estimation. The values of heritability for conformation traits were in the range from 0.06 to 0.63 and for longevity traits from 0.04 to 0.05. Low or intermediate genetic relationships between recorded linear traits and longevity trait were found. The correlations were lower for functional longevity. Body measurements showed negative genetic correlations with real as well as functional longevity (–0.12 to –0.29). The dairy character negatively correlated with longevity traits (–0.18 to –0.26). The muscularity and udder showed a zero correlation with functional longevity, while the feet and legs were not correlated with real longevity. The highest positive genetic correlations between real longevity and objectively scored linear type traits were found for hock (0.24), rear udder attachment (0.28), fore udder length (0.16) and central ligament (0.11). On the contrary, the correlation between the udder depth and the milk-corrected longevity was positive (0.28) and higher than in the case of real longevity.

Keywords: cattle; Czech Fleckvieh; longevity; conformation traits; genetic correlation

Functional traits in dairy cattle such as longevity and conformation are economically important. Longevity combines all of the characteristics that are directly associated with a cow's ability to successfully stay in the herd. When a cow becomes unprofitable due to illness, injury, reproductive inefficiency or low milk production, it is likely to be culled. Extended herd life is economically beneficial due to lower heifer replacement costs and a higher proportion of cows producing at a mature age (Van Arendonk, 1991). The need to consider herd life in selection programmes in addition to economic traits such as milk yield has increased in the last two decades, since herd life in many dairy populations has deteriorated due to intensive selection for enhanced productivity.

Ducrocq (1992) distinguished between two types of longevity: (real) longevity that can be observed directly and is strongly dependent on milk yield and functional longevity, that is the ability of the cow to avoid culling for other reasons than low performance. Culling based on low milk production is often referred to as voluntary culling, and culling based on health or reproductive problems is termed involuntary culling.

Genetic improvement of longevity is difficult to achieve (Essl, 1998). The heritability of longevity is low (Vollema and Groen, 1997; Vukasinovic et al., 2001; Tsuruta et al., 2005), and one must wait for the animal or its relatives to leave the herd before obtaining a direct measurement of herd life and before subsequent genetic evaluation. A possible

Supported by the Ministry of Agriculture of the Czech Republic (Project No. QH 71275).

solution is to combine culling data with indirect predictors that are more heritable and are measured earlier in life. Linear type traits are relatively easy to measure, and such information is generally available in a cow's first lactation. They are correlated with longevity to a certain degree, and therefore represent logical predictors (Vollema and Groen, 1997; Vukasinovic et al., 2002; Bouška et al., 2006). However, only a low to moderate genetic relationships between various type traits and the yield-corrected longevity were reported. The closest relationships were generally found for udder attachment, udder depth, teats, and angularity of rear legs (Sölkner and Petschina, 1999; Vukasinovic et al., 2002; Strapák et al., 2005; Bouška et al., 2006). Because of these low co-relationships, the greater reliability of indirect genetic evaluation for functional longevity using type traits such as indicator variables becomes questionable (Essl, 1998). However, as suggested by Vukasinovic et al. (2002), the reliability of the combined evaluation is always higher than the reliability of the direct evaluation alone. According to their results, the greatest increase in reliability can be observed in young bulls with mostly censored daughters.

Sölkner and Petschina (1999) analysed the phenotypic relationships of various type traits obtained by a linear scoring system with the length of the 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. (2006) described the relationship between linear type traits and longevity traits of Czech Fleckvieh cows. Positive relationships were found particularly for udder traits. Fore udder, rear udder attachment, central ligament, and udder depth appear to be potential indicators of cow longevity.

In Bavarian Fleckvieh, Strapák et al. (2005) found positive correlations between type traits and longevity traits when they analysed the genetic relationship between longevity traits and selected production, reproduction and type traits using estimated breeding values for longevity. The correlations between longevity and udder traits were positive but lower for functional longevity.

The main objective of the present study was to investigate the genetic relationships between longevity expressed as the length of productive life and conformation traits reflecting udder, feet and legs, and overall type and body measurements in Czech Fleckvieh cows comparing these correlations for real longevity and functional longevity.

MATERIAL AND METHODS

The data set consisted of 58 493 Czech Fleckvieh cows first calved from 1994 to 2003. All cows used in the analysis were scored for conformation between the 60th and 180th day of the first lactation. The cows were culled before the moment of data collection (culled from 1997 to 2006). The average culling age was 1 766 days, with a minimum of 750 days and a maximum of 3 933 days. Longevity expressed as the number of days between the first calving and culling had an average of 892 days with a minimum of 31 days and a maximum of 2 972 days.

The following conformation traits were used: objectively scored linear type (LT) traits were height at sacrum, muscularity, rump length, rump width, rump angle, body depth, rear legs side view, hock, pastern, hoof angle, fore udder length, rear udder attachment, central ligament, udder depth, front teat placement, teat length, and teat width. The traits were scored on a nine-point scale. The body measurements (BM) in cm were height at withers, height at sacrum, chest girth, body depth, rump length, rump width. The aggregated traits (AT) scored in the interval between 50 and 100 points were dairy character, muscularity, feet and legs, udder.

Real longevity (LPL) included the number of days between the first calving and culling, i.e. length of productive life. Functional longevity (LPLF) was defined in the same way as the length of productive life but corrected for milk production.

Genetic correlations between longevity traits and conformation traits were estimated by bivariate runs using the program for variance component estimation VCE 4.0 by Groeneveld and Garcia Cortes (1998). The following model was used to analyse the data set:

$$Y_{ijklmno} = \text{herd}_i + \text{year}_j + \text{season}_k + \text{age}_l + \text{class}_m + \text{animal}_n + \text{MILK} + e_{ijklmno}$$

where:

$Y_{ijklmno}$ = observation of longevity or conformation trait
herd$_i$ = fixed effect of herd i
year$_j$ = fixed effect of year of first calving j
season$_k$ = fixed effect of season of first calving k
age$_l$ = fixed effect of age at first calving l

Table 1. Mean and standard deviation (SD) and estimated heritability of the traits analysed in bivariate runs with real longevity (LPL) or functional longevity (LPLF)

	Mean	SD	h^2 (LPL)	h^2 (LPLF)
Longevity (days)	892.9	535.32	0.05	0.04
Height at withers (cm)	134.5	4.23	0.39	0.39
Height at sacrum (BM) (cm)	137.4	4.19	0.44	0.44
Chest girth (cm)	195.3	7.94	0.25	0.25
Body depth (BM) (cm)	77.4	4.79	0.63	0.63
Rump length (BM) (cm)	52.8	2.12	0.30	0.30
Rump width (BM) (cm)	51.9	2.70	0.28	0.28
Dairy character (points)	78.5	5.33	0.23	0.23
Muscularity (AT) (points)	77.6	5.03	0.30	0.30
Feet and legs (points)	76.3	7.28	0.09	0.09
Udder (points)	78.1	5.20	0.16	0.16
Height at sacrum (LT) (points)	5.1	1.42	0.42	0.42
Muscularity (LT) (points)	5.2	1.09	0.28	0.28
Rump length (LT) (points)	5.2	1.08	0.28	0.28
Rump width (LT) (points)	5.2	1.36	0.40	0.40
Rump angle (points)	5.7	0.95	0.25	0.25
Body depth (LT) (points)	5.9	1.04	0.23	0.23
Rear legs side view (points)	5.6	0.97	0.14	0.14
Hock (points)	6.3	0.93	0.19	0.19
Pastern (points)	4.7	0.94	0.09	0.09
Hoof angle (points)	4.9	1.29	0.07	0.06
Fore udder length (points)	5.3	1.11	0.19	0.18
Rear udder attachment (points)	6.4	1.08	0.20	0.20
Central ligament (points)	3.9	1.59	0.14	0.14
Udder depth (points)	6.4	0.97	0.23	0.22
Front teat placement (points)	5.0	0.84	0.14	0.14
Teat length (points)	5.0	1.07	0.26	0.26
Teat width (points)	5.2	1.14	0.21	0.21

$class_m$ = fixed effect of classifier m, only for conformation traits
$animal_n$ = random effect of animal n connected with pedigree; the pedigree included 205 098 animals
MILK = fixed linear regression of milk production in first lactation, only for LPLF
$e_{ijklmno}$ = random residual effect o

Each bivariate analysis included the equation for the longevity trait and that for the conformation trait. Because longevity was defined in two ways, as real, that is uncorrected for milk production (LPL), and as functional, or corrected for milk production (LPLF), two sets of analyses were created. Each of them included all the conformation traits analysed.

Therefore, there are two sets of results presented in this study.

RESULTS AND DISCUSSION

Heritability

In addition to the means and standard deviations of the traits, Table 1 presents the estimated heritability from the bivariate analyses of conformation and longevity traits. A comparison of the results for longevity uncorrected for milk production (LPL) and that corrected for milk production (LPLF) revealed that the heritability was almost the same. The heritability for LPL (0.05) was slightly higher than that for LPLF (0.04).

For Dutch Black and White cows, Vollema and Groen (1997) reported slightly higher estimates for herd life (0.10, 0.13) and for functional herd life (0.07, 0.09), depending on the data set used. A much higher heritability of functional longevity (0.20) for Simmental cattle was found by Vukasinovic et al. (2002).

Body measurements showed heritability between 0.25 (chest girth) to 0.64 (body depth (BM)). The heritability for height at withers (0.39) and height at sacrum (BM) (0.44) was higher than that for the majority of the conformation traits analysed.

The heritability of the aggregate traits varied between 0.30 (muscularity (AT)) and 0.09 (feet and legs). The heritability for dairy character and udder was 0.23 and 0.16, respectively.

Vollema and Groen (1997) published higher estimates of heritability for the udder (0.32, 0.34) as well as for feet and legs (0.29, 0.41).

Objectively scored linear type traits showed heritability from 0.07 (hoof angle) to 0.42 (height at sacrum (LT)). The most frequent values of heritability were around 0.20. The estimated values were similar to or lower than those obtained in other cattle populations (e.g., Vollema and Groen, 1997; Vukasinovic et al., 2002).

The highest heritability was found for the traits describing body measurement (height at sacrum (LT), muscularity (LT), rump length (LT), rump width (LT), rump angle, body depth (LT)). Vukasinovic et al. (2002) found slightly higher heritability for body depth (0.36), rump length (0.44) and rump angle (0.37).

Those traits associated with feet and legs (rear legs side view, hock, pastern, hoof angle) showed low heritability. The highest value of heritability among these traits occurred in the hock (0.19). For Dutch Black and White cows, Vollema and Groen (1997) found heritability 0.17 and 0.32 for rear legs side view. Vukasinovic et al. (2002) reported values of heritability ranging from 0.22 to 0.27 for rear legs side view, hock, pastern, and hoof angle.

For udder traits, the highest values of heritability were found for teat length (0.26) and udder depth (0.23). The lowest heritability occurred for central ligament (0.14) and front teat placement (0.14). Vollema and Groen (1997) reported heritability 0.26, 0.31 and 0.34 for udder depth and 0.20, 0.25 and 0.27 for teat placement. The values of heritability for udder depth and further udder traits found by Vukasinovic et al. (2002) were over 0.31. Those for teat placement and length were 0.48 and 0.51, respectively.

Genetic correlations

Table 2 contains estimated genetic correlations between longevity traits on the one hand and conformation traits on the other. Positive genetic correlations indicate that higher values of traits, body measures or conformation scores are connected with a longer herd life and vice versa.

The body measurements negatively correlated with LPL as well as with LPLF, although these correlations for chest girth, rump length (BM) and rump width (BM) were closer with LPL (–0.19 to –0.29) than with LPLF (–0.12 to –0.18). The correlations for height at withers, height at sacrum (BM) and body depth (BM) were almost the same for both longevity traits. In agreement with these findings, smaller and narrower cows are more likely to have a longer herd life, whereas larger and broader cows are expected to be culled earlier.

For the aggregate traits, dairy character showed negative correlations with longevity traits, which were lower in the LPLF (–0.18) than in the LPL (–0.26). For muscularity (AT), a stronger negative correlation (–0.23) was found with LPL, but a slightly positive correlation (0.03) with LPLF. The feet and legs showed an almost zero genetic correlation with LPL, and a positive but low correlation with LPLF (0.09). On the contrary, the correlation between udder and LPL was positive and stronger (0.28) than most of the correlations estimated for aggregate traits. However, the genetic correlation between udder and LPLF was almost zero.

Table 2. Genetic correlations between longevity traits and conformation traits

	r_g (LPL)[1]	r_g (LPLF)[2]
Height at withers (cm)	–0.23	–0.26
Height at sacrum (BM) (cm)	–0.22	–0.23
Chest girth (cm)	–0.24	–0.16
Body depth (BM) (cm)	–0.12	–0.14
Rump length (BM) (cm)	–0.19	–0.12
Rump width (BM) (cm)	–0.29	–0.18
Dairy character (points)	–0.26	–0.18
Muscularity (AT) (points)	–0.23	0.03
Feet and legs (points)	–0.01	0.09
Udder (points)	0.28	–0.02
Height at sacrum (LT) (points)	–0.23	–0.24
Muscularity (LT) (points)	–0.21	0.01
Rump length (LT) (points)	–0.17	–0.10
Rump width (LT) (points)	–0.23	–0.14
Rump angle (points)	0.03	0.07
Body depth (LT) (points)	–0.16	–0.23
Rear legs side view (points)	0.00	–0.08
Hock (points)	0.24	0.17
Pastern (points)	–0.10	0.12
Hoof angle (points)	–0.15	–0.10
Fore udder length (points)	0.16	–0.11
Rear udder attachment (points)	0.28	–0.08
Central ligament (points)	0.11	–0.06
Udder depth (points)	–0.02	0.28
Front teat placement (points)	0.22	0.20
Teat length (points)	–0.16	–0.14
Teat width (points)	–0.24	–0.29

[1]r_g (LPL) – genetic correlations with length of productive life
[2]r_g (LPLF) – genetic correlations with length of productive life corrected for milk production in the first lactation

Similarly to our findings, Strapák et al. (2005) reported positive correlations of udder with longevity (0.24) and a lower one with functional longevity (0.11). For muscularity, they found a negative correlation with longevity (–0.06) and a positive one with functional longevity (0.08). In contrast, Vollema and Groen (1997) reported no genetic correlation between udder and herd life, and a closer correlation (0.24) with functional herd life for Dutch Black and White cows. Similarly, correlations between feet and legs in uncorrected as well as milk-corrected herd life (0.15; 0.24) were higher than in our study.

Regarding negative correlations between dairy character and both longevity traits, it appears that cows with a more desirable appearance are more likely to be culled than cows with lower values for dairy character.

Muscularity (AT) showed a negative relationship with LPL, probably due to milk production, because there was no correlation between muscularity and LPLF.

Positive genetic correlations of feet and legs with LPLF confirmed the assumption that the feet and legs are potential indicators of a cow's longevity. However, the relationship found is only slight.

The results for the udder indicate that an animal with a high udder score has an advantage in longevity based on higher milk production. After correction for milk production, the udder score showed practically no relationship to longevity and could not be used as a predictor of herd life.

Objectively scored linear type traits demonstrated the following genetic correlations with longevity traits (Table 2).

Height at sacrum (LT), muscularity (LT), rump length (LT), rump width (LT), rump angle and body depth (LT) strongly negatively correlated with LPL except for rump angle (0.03; 0.07). For LPLF, the genetic correlations with rump length (LT) and rump width (LT) were lower than those for LPL. On the contrary, the body depth (LT) and rump angle showed higher genetic correlations with LPLF than with LPL. For height at sacrum (LT), the same genetic correlations with LPL and LPLF were found. A substantial change was found concerning muscularity (LT). The genetic correlation with LPLF was zero.

Similarly, negative Pearson correlation coefficients with milk-uncorrected longevity for muscularity (–0.08) and rump width (–0.03) were found by Bouška et al. (2006) in Fleckvieh cows. They reported different results for rump angle (–0.14).

In Swiss Simmental, the genetic correlation between milk-corrected longevity and muscularity (0.01) found by Vukasinovic et al. (2002) corresponded to our results. The correlations between milk-corrected longevity and rump length (–0.08) or rump angle (–0.4) were only partially consistent with our findings.

The correlations for height at sacrum (LT) and rump length (LT) were the same as those found for the same traits expressed as body measurements. Similarly, the genetic correlations with muscularity (LT) corresponded to the muscularity (AT) expressed as an aggregate trait. We can conclude that smaller and narrower cows live longer than larger cows. The positive genetic correlation with LPLF classifies rump angle (LT) among the potential indicators of cow's longevity.

Foot and leg traits were represented by rear legs side view, hock, pastern, and hoof angle. The genetic correlations with the analysed longevity traits are different for each of them. The highest one was found for hock, positive and higher for the LPL (0.24) than for the LPLF trait (0.17). The pastern negatively correlated with LPL (–0.10) and positively (0.12) with LPLF. Different relations due to the adjustment for milk production provide evidence that a certain relationship exists between milk production and the pastern. The correlations for hoof angle were negative and higher for LPL (–0.15) than for LPLF (–0.10). Rear legs side view showed a zero correlation with LPL and a low negative correlation (–0.08) with LPLF.

In agreement with our results, Bouška et al. (2006) published a low positive Pearson correlation coefficient with milk-uncorrected longevity for rear legs set (0.01) and a negative one for foot angle (–0.08). Vollema and Groen (1997) reported rear legs side view to be negatively correlated with herd life (–0.10) and functional herd life (–0.21). Strapák et al. (2005) reported positive correlations of longevity traits, both uncorrected and milk-corrected, with selected form and foot and leg traits (0.03 to 0.16).

Results similar to our findings were published by Vukasinovic et al. (2002). They found a negative genetic correlation between milk-corrected longevity and rear legs side view (–0.12), and positive genetic correlations with hock (0.17) and with pastern (0.05).

The estimated genetic correlation of foot and leg traits with LPLF confirmed their influence on the length of the cow's herd life. Low values of correlations are probably caused by the nonlinear relationship between these type traits and longevity because of the intermediate optimum of these traits. The results imply that cows with straighter legs and pastern, normal hock and lower hoof angle show longer functional longevity.

Fore udder length, rear udder attachment, and the central ligament showed positive genetic correlations with LPL, while the genetic correlation for udder depth was negative and low (–0.02). In contrast, the genetic correlations with LPLF for fore udder length, rear udder attachment, and the central ligament were negative and lower than those with LPL. The genetic correlation between udder depth and LPLF was positive (0.28) and higher than that for LPL.

In Fleckvieh cows, a positive relationship between stayability and udder traits was found by Bouška et al. (2006). They reported Pearson correlation coefficients with milk-uncorrected longevity for fore udder length (0.18), rear udder attachment (0.12), central ligament (0.16), and udder depth (0.18). This is in accordance with our findings except for udder depth.

Positive correlations between longevity and front udder (0.17), rear udder (0.17) and udder attachment (0.19) were found by Strapák et al. (2005). The correlations for the same traits were substantially lower for functional longevity (front udder 0.02, rear udder –0.01, udder attachment 0.12).

In accordance with our findings, Vollema and Groen (1997) reported a weak genetic correlation with milk-uncorrected longevity for udder depth but a strong correlation between udder depth and milk-corrected longevity (0.39). Contrary to our results, they reported a negative correlation (–0.06) between the central ligament and herd life and a positive one (0.08) between the central ligament and functional herd life.

Similarly, Vukasinovic et al. (2002) found positive genetic correlations of milk-corrected longevity not only with suspensory ligament (0.16) and udder depth (0.35) but also with fore udder (0.32) and with rear udder attachment (0.35).

We can conclude that positive correlations between LPL and fore udder length, rear udder attachment and central ligament are based on higher milk production because of the negative correlation between these traits and LPLF. This corresponds to the conclusions for the udder (AT), aggregate trait. On the contrary, the udder depth showed no correlation with LPL but a positive correlation with LPLF. We can assume that cows with moderately deep udders live longer regardless of milk production. The positive genetic correlation with milk-corrected longevity classifies udder depth among the potential indicators of cow longevity.

Udder traits associated with teats were front teat placement, teat length and teat width. These showed similar correlations with both longevity traits. For front teat placement they were positive (0.22; 0.20), and for teat length (–0.16; –0.14) and teat width (–0.24; –0.29) they were negative.

In contrast to our results Bouška et al. (2006) reported a negative Pearson correlation coefficient for teat placement (–0.06) and a positive one for teat length (0.06) with uncorrected longevity. For fore teat placement, Vollema and Groen (1997) found a slightly negative correlation (–0.04) with herd life but a slightly positive one (0.08) with functional herd life. Similarly to our results, Vukasinovic et al. (2002) reported a negative correlation of milk-corrected longevity with teat length (–0.40) and a positive one with teat placement (0.11).

The correlation between longevity traits and teat-associated traits seems to be independent of milk production. According to the estimated correlations, cows with shorter and narrower teats have an advantage concerning longevity.

CONCLUSIONS

The results of the present study indicate the existence of slight or intermediate genetic relationships between the recorded linear traits and longevity expressed as the length of productive life, whether real or functional. Once functional longevity was included in the analysis, the genetic correlations were reduced. Fore udder length, rear udder attachment, and the central ligament were positively correlated with real longevity. Due to positive genetic correlation with milk-corrected longevity, udder depth belongs among the potential indicators of cow functional longevity.

The estimated correlations may be time-dependent and should be verified in defined intervals. The results can be applied in future research and breeding value estimation of longevity traits in Czech Fleckvieh cattle.

Acknowledgments

We thank Mr. Luděk Bartoň and Mrs. Lois Russell for their editorial assistance with this manuscript.

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Received: 2008–08–06
Accepted after corrections: 2009–03–24

Corresponding Author

Ing. Ludmila Zavadilová, Institute of Animal Science, Přátelství 815, 104 00 Prague-Uhříněves, Czech Republic
e-mail: lida.zavadilova@seznam.cz