https://doi.org/10.17221/102/2021-CJAS

Fleckscore system of exterior evaluation as a more accurate indirect predictor of longevity in Slovak Simmental dairy cows

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Citation: Strapáková E., Strapák P., Candrák J., Pavlík I., Dočkalová K. (2021): Fleckscore system of exterior evaluation as a more accurate indirect predictor of longevity in Slovak Simmental dairy cows. Czech J. Anim. Sci., 66: 487–494.

Abstract: The goal of the work was to discover the influence of conformation traits evaluated by the Fleckscore system on the length of productive life of Slovak Simmental dairy cows. Evaluation of body conformation traits according to the Fleckscore system was performed on 3 452 cows. The relationship of individual traits to longevity was analysed using the Weibull proportional hazard model. The results confirmed that smaller and longer cows, which were well muscular and with a deeper body, had a lower risk of early culling than cows in the reference group. Hock angularity, pastern and hoof height scored with low or high marks were associated with an early culling of cows. In terms of the length of productive life, a slightly more elastic pattern is required. Cows with a deeper udder and a stronger and tighter fore udder attachment, which were also average in notching and height central ligament and centrally placed teats, reached longer productive life.

Keywords: conformation traits; cattle; length of productive life, survival analysis; Weibull model

One of the main goals of the dairy industry is to achieve high milk production with the lowest possible costs of herd maintenance. In recent years, the selection criteria preferred animals that combine the best production and reproduction with longevity and body conformation traits (Miglior et al. 2005). Longevity is a trait that reflects good health and good reproduction results of the cows. The cows that remain in the herd for a long time give more options for voluntary culling of farmers based on milk production (Sewalem et al. 2008).

Longevity is easily recorded, but the time until the information is available is very long. Reliable data are obtained only after the death of a cow. The use of records about living animals at the end of the study (censored data) in evaluation brings a shortening the time to obtain evaluation results (Ducrocq et al. 1988; Vukasinovic et al. 2001). Survival analysis is a method that combines censored and uncensored (culled animals) information, enables a proper statistical treatment of censored records, and accounts for nonlinear characteristics

Supported by the KEGA Institution, Slovakia (Project No. 012SPU-4/2019).

https://doi.org/10.17221/102/2021-CJAS

of longevity data (Meszaros et al. 2013). The survival analysis approach is based on the concept of hazard rate that can be modelled for all records (uncensored and censored). Famula (1981) was the first author who proposed survival analysis as a method for analyzing longevity data in dairy cattle.

Longevity is a trait with very low heritability (Daliri et al. 2008). Therefore, it seems more appropriate to use other correlated traits for the indirect prediction of longevity. Many authors reported a relationship between longevity and body conformation traits (Vacek et al. 2006; Pantelic et al. 2010), which achieve moderate values of heritability (Pantelic et al. 2010). In addition, type scoring is usually performed during the first lactation; thus, it brings earlier information related to longevity (Novotny et al. 2017). Caraviello et al. (2003) and Zavadilova et al. (2011) proposed that linear type traits, mainly udder, feet, and legs traits, can be used as predictors for longevity.

Based on scientific knowledge about the effect of udder traits and feet and legs traits on longevity, a new system of body conformation traits evaluation in Simmental cattle so-called Fleckscore system was introduced. International system Fleckscore is the most accurate way of the main conformation traits scores calculation in Simmental breed in Europe. A benefit of the system is the lactation-specific calculation of proposed marks, and the scores awarded are subjected to a clearly comprehensible derivation from the single marks according to the reference for optimizing the length of productive life (Tanzler et al. 2015).

The aim of the study was to evaluate the influence of the conformation traits on the length of functional, productive life in Slovak Simmental dairy cows by the Weibull proportional hazard model.

MATERIAL AND METHODS

The data set included 3 452 Slovak Simmental dairy cows from 53 herds in the Slovak Republic born from 2009 to 2018. The analysed records of the length of productive life and exterior traits were provided by the Breeding Services of Slovak Republic, s.e. and Slovak Simmental Cattle Breeders Association.

The evaluation of exterior traits was performed by the evaluator from January 2019 to August 2020. 95.26% of cows were evaluated at the first lactation, others in the 2nd to 7th lactations.

All cows had their exteriors scored according to the international methodology of exterior evaluation called the Fleckscore system (Tanzler et al. 2015). Fourteen single linear traits were scored on a scale of 1–9. Body frame traits were measured in cm. For easier interpretation of the results, body frame traits values were transformed into six classes. The composite traits and total score were presented on a scale of 68–93 points in primiparous cows with a possibility of increasing the scale in the case of multiparous cows. The total score consists of the composite traits ratio: 10% frame, 20% muscularity, 30% feet and legs and 40% udder (Tanzler et al. 2015).

Longevity was expressed as a length of the functional productive life (FPL) that described the ability of cows to delay involuntary culling due to infertility, reproductive problems or illness, that is culling due to reasons other than milk production. FPL includes a period of time (in days) between the first calving and the culling of cows or data censoring. Information about the cows that were alive by the end of the study and the cows that did not reach milk yield higher than 1 700 kg were censored. Cows aged at first calving higher than 1 200 days and less than 600 days were excluded from the analysis. A high value of censored records (83.6%) was achieved because mainly primiparous cows were evaluated (Table 1).

The evaluation was performed using the Weibull proportional hazard sire model:

$$\Lambda(t) = \Lambda_0(t) \exp(p + m + h + a + hys + s + t) \quad (1)$$

where:

$\Lambda(t)$ – hazard function of an animal at time t;

$\Lambda_0(t)$ – Weibull baseline hazard function;

p – time-dependent effect of parity (six classes);

m – time-dependent effect of milk yield expressed as a standard deviation (SD) from within-herd-year average: (1) more than +2 SD from herd-year average, (2) between +1 SD from herd-year average and +2 SD form herd-year average, (3) between

Table 1. Simple statistics of longevity data

	Average LFPL	Min. LFPL	Max. LFPL	n
Censored records	511.71	1	3 090	2 886
Uncensored records	367.45	36	1 275	566

LFPL = length of functional productive life

https://doi.org/10.17221/102/2021-CJAS

−1 SD and +1 SD from herd-year average, (4) between −1 SD and −2 SD from herd-year average, (5) less than −2 SD from herd-year average (6) non-standard or uncompleted lactations;

h – time-dependent effect of annual change in herd size: (1) decrease > 30%, (2) decrease of 0–30%, (3) unchanged state, (4) increase of 0–30% (5) increase > 30%;

a – time-independent effect of age at first calving in days: (1) 600–690, (2) 691–780, (3) 781–870, (4) 871–960, (5) 961–1 200 days;

hys – random time-dependent effect of herd × year × season interaction (a normal distribution with change points at April 1st and October 1st of each year; variance = 0.37);

s – random time-independent effect of sire following a multi-normal distribution with a variance of 0.02;

t – time-independent effect of exterior traits.

Each trait was included in the analysis separately.

The relationship between the FPL and the exterior trait was expressed as a relative risk of culling (RRC). The reference level of culling risk was set to 1, which was the level with the largest number of uncensored cows. RRC values > 1 indicate a higher culling risk and vice versa.

Data preparation and summary statistics were performed by SAS v9.4 (SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Table 2 displays a summary statistic of measured frame traits, linear traits and composite traits. The median for linear and composite traits was between four and six points. Some traits reach the desired expression at higher values (eight and nine points), so the median did not always express the optimal development of the traits.

Our results pointed out a higher frame of evaluated Slovak Simmental cows in comparison with dairy Czech Fleckvieh cows (Novotny et al. 2017). The average scores for feet and legs and udder were 81.06 and 79.96, respectively (Table 2). Novotny et al. (2017) stated a lower average score for feet and legs and udder trait by 5.46 and 2.67 points compared to our results.

Figure 1 displayed the highest contribution of muscularity on the longevity of cows, followed by linear traits as fore udder length, central ligament and pastern. Body frame traits like cross height and back length had the lowest effect on the FPL. Linear traits of udder and feet and legs reached the strongest relationship with longevity in comparison with other composite traits. According to our analysis, pastern and hoof height were traits with a high contribution to the likelihood of longevity (Figure 1). Sewalem et al. (2005), Zavadilova et al. (2011) and Caraviello et al. (2003) confirmed our results that selected linear traits of udder and feet and legs had the highest contribution to the likelihood of functional longevity in dairy cows.

Composite traits

Figure 2 shows the risk of culling for composite traits of cows. The cows from the medium body frame to the large frame (81–83 points) represented the reference group. The cows with a rating of 74–76 and 71–73 points achieved a lower risk of early culling (0.736 and 0.86) than cows in the reference group. These results may have been caused by the fact that smaller cows produce milk more efficiently with respect to the amount of maintenance ration (Yerex et al. 1988). Another reason may be the selection of animals suitable for technological breeding systems. The cows with a score of 90–93 had the lowest risk of culling (0.328) but these results were unreliable due to the low number of culled cows. Based on the negative correlation between longevity and frame, Novotny et al. (2017) assumed that cows with a smaller body frame have a genetic predisposition to longer productive life. Zavadilova et al. (2011) found that larger, broader, and more muscular Simmental cows with longer and wider rump had a higher risk of being culled compared with the smaller and narrower cows, which is a different result than the one found during our analysis.

Cows with 81–83 points for feet and legs represented the reference group. The cows with the lowest number of points achieved up to 2.3 times higher risk of being culled compared with cows in the reference group. The lowest risk of culling, which was 1.1 times lower than at the reference level, was achieved by animals with 77–79 points (Figure 2). Sewalem et al. (2005) also stated more than 2.7 times higher risk of culling for cows classified as poor in feet and legs compared to cows classified as a good plus in Ayrshire cattle. Berry et al. (2005) showed a similar trend of culling in compared to our results.

https://doi.org/10.17221/102/2021-CJAS

Table 2. Summary statistic of conformation traits

Variable	Average ± SE (points)	SD	Min.	Max.	*n*	Median
Cross height (cm)	144.31 ± 0.07	4.36	124	158	3 452	145
Rump length (cm)	53.31 ± 0.05	2.68	0	67	3 452	53
Hip width (cm)	55.76 ± 0.04	2.56	45	72	3 452	56
Back length (cm)	83.39 ± 0.07	3.90	65	100	3 452	84
Body depth (cm)	82.92 ± 0.08	4.78	54	99	3 452	83
Chest circumference (cm)	197.66 ± 0.14	8.33	160	230	3 452	200
Linear traits (score)						
Hock angularity	5.15 ± 0.02	1.07	1	9	3 452	6
Hock development	6.03 ± 0.02	0.91	1	9	3 452	5
Pastern	5.16 ± 0.02	1.16	1	9	3 452	5
Hoof height	4.78 ± 0.02	1.01	1	8	3 452	5
Fore udder length	5.27 ± 0.02	1.10	1	9	3 452	6
Central ligament	5.46 ± 0.03	1.75	1	9	3 452	6
Udder depth	5.64 ± 0.03	1.61	1	9	3 452	6
Rear teat attitude	5.33 ± 0.03	1.51	1	9	3 452	5
Teat length	5.03 ± 0.02	1.00	2	9	3 452	5
Teat thickness	5.23 ± 0.01	0.81	1	9	3 452	4
Front teat placement	4.21 ± 0.02	1.17	2	8	3 452	5
Rear udder length	5.10 ± 0.02	1.03	1	9	3 452	5
Fore udder attachment	4.59 ± 0.03	1.49	1	9	3 452	6
Rear teat placement	5.67 ± 0.02	1.27	1	9	3 372	6
Composite traits (score)						
Frame	5.52 ± 0.03 (81.35)	1.78	1	9	3 452	5
Muscularity	5.05 ± 0.02 (80.16)	1.08	1	9	3 452	6
Feet and legs	5.42 ± 0.03 (81.06)	1.61	1	9	3 452	5
Udder	5.01 ± 0.03 (79.96)	1.64	1	9	3 452	5
Total score	4.64 ± 0.01	0.58	2	5	3 449	5

SD = standard deviation; SE = standard error

In terms of muscularity assessment, the reference group consisted of cows with a straight haunch (77–79 points) (Figure 2). Cows with an extremely concave haunch (71–73 points) reached a 3.9 times higher risk of culling compared to the group mentioned above. In other groups with increasing points, the risk of culling had a decreasing tendency. The lowest risk of culling compared with the reference group was found on more muscular cows with a score of 84–86 points. Sewalem et al. (2005) showed a more than three times higher risk of culling in Ayrshires cows with a poor dairy character (more muscular cows) in comparison with cows classified as a good plus.

The udder has the most important relationship to longevity of all composite traits (Figure 1). Cows with a classification score of udder from 84 to 86 points had the highest chance to reach a longer productive life than other cows. The highest risk of culling, 1.802 times higher compared with cows in the reference group (81–83 points) was estimated in the group of cows that scored 90–93 points (Figure 2). Zavadilova et al. (2011) stated that the optimum for udder is a class good plus (80–84 points). The authors confirmed that the cows with the highest-scoring achieved shorter productive life than cows in the reference group. According to Sewalem et al. (2005), the highest risk of culling was reached in the group of cows with a poor udder rating.

https://doi.org/10.17221/102/2021-CJAS

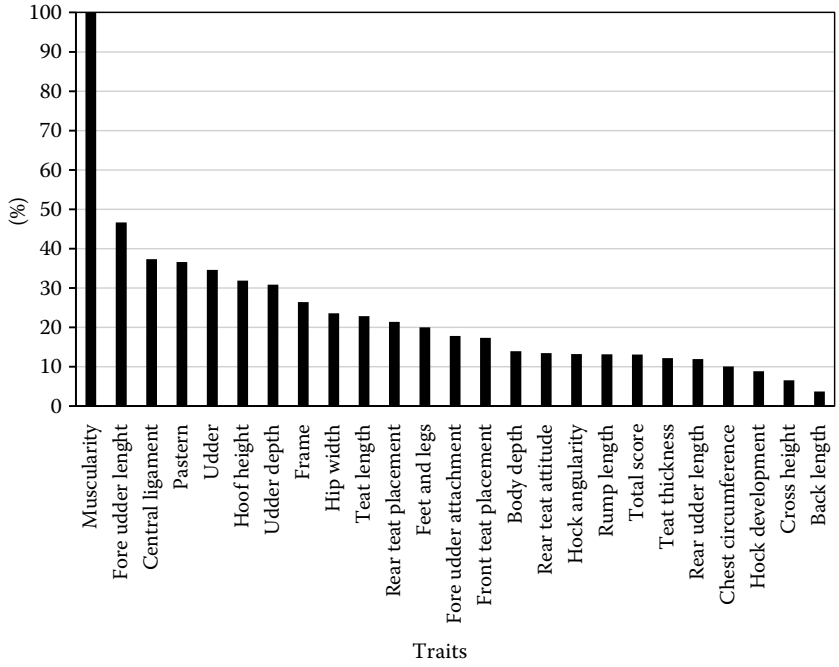

Figure 1. Contribution of the conformation traits to the likelihood for functional productive life

Body measurements

When assessing the cross height, almost all cows achieved a lower risk of culling than the ones in the 4th group (144–146 cm) (Table 3). The lowest risk of culling was recorded in cows with a cross height from 152 cm to 158 cm (class 6), which was 2.1 times lower compared to the reference group. However, the results could be affected by the small number of animals in the group (n = 6). The smaller cows, in the class of 1 to 3, reached a higher length of productive life than the ones in the reference group. The reference group for the hip-width trait consisted of cows in class 3 (54–56 cm). The lowest risk of early culling, which was 1.4 times lower in comparison with the reference group was found in class 5 (60–62 cm). Cows with a rump length shorter than 47 cm (class 1) had a 1.8 times higher risk of early culling than the group of cows with a rump length from 54 cm to 56 cm. The lowest risk of early culling (0.485) was achieved by the cows in class 6, where only five uncensored records were examined. The relative risk of culling for the trait back length had a decreasing trend with an increasing score. It means that the cows with a back length shorter than 83 cm were at risk of being culling sooner than the other cows. A comparable trend with body length traits was also found for the body depth. The group of cows with a body depth of less than 83 cm (classes 1–3) reached a higher risk of culling. Cows with values higher than 88 cm (classes 5 and 6) showed a lower risk. A group of cows with chest circumference from 199 cm to 206 cm was determined as a reference level. Cows with a chest circumference smaller than 182 cm (class 1) achieved the highest risk of culling (1.142). In contrast, animals with a chest circumference greater than 215 cm had a risk of culling 1.6 times lower than cows in the reference class (Table 3). Zavadilova et al. (2011) confirmed our results, that tall cows had poorer longevity. Schneider et al. (2003) reported a higher risk of culling for shorter animals. Contrary to our results, Zavadilova et al. (2011) found a significant decrease in longevity for cows with a deep body. Setati et al. (2004) confirmed that a shallow body depth was associated with

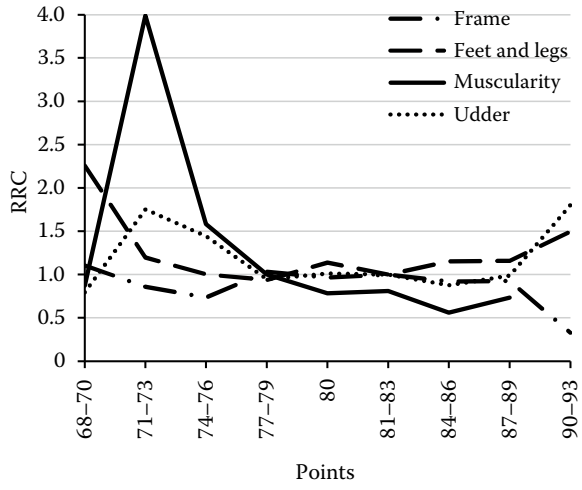

Figure 2. Relative risk of culling (RRC) for composite traits

https://doi.org/10.17221/102/2021-CJAS

Table 3. Relative risk of culling for body frame traits

Class	Cross height		Hip width		Rump length		Back length		Body depth		Chest circumference	
	level (cm)	RRC	level (cm)	RRC	level (cm)	RRC	level (cm)	RRC	level (cm)	RRC	level (cm)	RRC
1	124–133	0.959	≤ 50	1.002	≤ 47	1.789	≤ 75	1.038	≤ 75	1.402	≤ 182	1.142
2	134–137	0.906	51–53	0.949	48–50	0.858	76–79	1.126	76–79	1.013	183–190	0.996
3	138–143	0.976	54–56	1.000	51–53	0.930	80–83	1.006	80–83	1.253	191–198	1.209
4	144–146	1.000	57–59	0.994	54–56	1.000	84–87	1.000	84–87	1.000	199–206	1.000
5	147–151	1.001	60–62	0.715	57–59	1.022	88–91	0.923	88–91	0.926	207–214	0.964
6	152–158	0.482	≥ 63	–	≥ 60	0.485	≥ 92	0.672	≥ 92	0.922	≥ 215	0.637

RRC = relative risk of culling

increased longevity. Sewalem et al. (2005) stated that there are higher risks of culling (1.34) for both shallow and deep body animals. Novotny et al. (2017) confirmed a negative correlation (r_g = –0.19) between body depth and functional longevity which showed that cows with shallower bodies reached longer productive life.

Feet and legs traits

Cows with a score of five points for the hock angularity trait (correct posture of rear legs) represented the reference class (Table 4). Scores that were either too low or high indicate less chance of reaching a higher productive life, which was also confirmed by Caraviello et al. (2003), Sewalem et al. (2005). The lowest risk of culling (0.554) was probably influenced by the small number of culled animals in the group with a score of 2 (Table 4). The optimum score of 9 for the hock development (very dry hock) represents the lowest risk of animal culling (0.851). Novotny et al. (2017) confirmed a positive genetic correlation (r_g = 0.14) between hock trait and functional longevity. It means that dry and fine hock predicts a longer productive life.

When evaluating the pastern, cows with a very low angle of the pastern (score 1) achieved up to 5.8 times higher risk compared to the reference group. In contrast, cows, which scored 3, had a risk 1.1 times lower than the average. Cows with a steeper angle of pastern had a higher risk of culling in comparison with the average development of this trait. Zavadilova et al. (2009) defined the intermediate optimum (score 5) of pastern and rear legs side view. Cows with low or high scores achieved a shorter length of productive life than cows in the reference level.

The results for the evaluation of the hoof height trait indicate that the cows with a flatter and higher hoof (2 and 7 scores) achieved a higher risk of being culled than cows with an average expression of this trait (Table 4). In general, a lower-scoring of the feet and legs is associated with a steep or sabre-like posture, which causes a higher risk of negative selection due to the gait dysfunction or pastern (Zavadilova et al. 2009).

Udder traits

A well-formed udder is a precondition for high milk production, and its high scoring brings the op-

Table 4. Relative risk of culling for feet and legs traits

Score	Development	Hock angularity	Hock development	Pastern	Hoof height
1	extremely below average	5.222	–	5.796	–
2	well below average	0.554	1.863	2.055	2.498
3	below average	1.000	1.037	0.926	0.915
4	slightly below averge	0.977	0.914	0.979	1.083
5	average	1.000	1.151	1.000	1.000
6	slightly above average	1.076	1.000	1.061	0.951
7	above average	0.935	0.981	1.356	1.402
8	well above average	2.076	0.990	1.429	–
9	extremely above average	1.317	0.851	–	–

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portunity of avoiding voluntary culling. Table 5 displayed the risk of culling for the individual udder traits. The highest asset to the creation of the composite trait udder by the Fleckscore evaluation in connection with the optimization of longevity has four linear traits like udder depth (24%) fore udder attachment (14%), central ligament (12%) and front teat placement (12%) (Tanzler et al. 2015). Therefore, only these traits will be commented.

The highest number of uncensored records for udder depth occurred in the groups of cows with a score of 3–8 (Table 5). There was a clear result that cows with a shallower udder are at a higher risk of culling than cows with a deeper udder. The lowest risk, 1.2 times lower compared to the reference group, was achieved by the cows with a score of 7. The reference level for fore udder attachment consisted of cows with a score of 5. Cows with weak and loose fore udder attachment (score 3, 4) were at a higher risk of culling compared to cows with more strong and tight fore udder (score 6, 7). In this study, the risk of early culling for the cows with a score of 9 could be affected by a low number of animals (n = 3). The optimal score of nine points is required, but Simmental cows rarely achieved nine points. Cows with an extremely strong central ligament (score 8, 9) achieved the highest risk of culling (1.877 and 2.568) in comparison with the group of cows scored by six points. When assessing the front teat placement, we found out that cows with an extreme outside and extreme inside placement of the front teat obtained a higher risk of culling than the cows with a score of 4 (Table 5). Sewalem et al. (2005) reported that dairy cows with a better udder formation are less often excluded from the herd due to low productivity or the occurrence of mastitis. Breeders also perform a negative selection of animals with poorly shaped udder traits due to the requirements for machine milking.

Zavadilova et al. (2009), Schneider et al. (2003), and Caraviello et al. (2003) presented suspensory ligament, rear udder length, udder depth and teats thickness as udder traits with a linear relationship to longevity. Zavadilova et al. (2009) stated that the most important traits are fore udder length and rear udder attachment. Fleckvieh cows with a stronger central ligament reached a smaller risk of culling, while the cows with a deep udder and a short fore udder were more likely to be culled. Sewalem et al. (2005) discovered a linear relationship of culling risk for fore attachment, median suspensory ligament, rear attachment height and width, and udder texture show in Jersey and Ayrshire cattle. Cows with high scores had a longer productive life than cows with low scores. Berry et al. (2005) confirmed the findings that cows with lower scores of udder had an overall higher probability of being culled. Many authors claim that there is a genetic correlation between the measurements of longevity and the udder traits in the range 0.10 to 0.54 (Samore et al. 2010). Bouska et al. (2006) found the most significant relationships between fore udder (r = 0.18), udder depth (r = 0.18), central ligament (r = 0.16) and stayability. Given that some udder traits have a heritability higher than longevity, and the evaluation of this trait is performed sooner than longevity, the authors suggested it be used as a measure for an indirect evaluation of longevity.

Table 5. Relative risk of culling for udder traits

Score	FUL	RUL	CL	UD	FUA	FTP	RTP	RTA	TL	TT
1	39.879	0.000	1.631	0.829	0.970	1.112	0.807	0.869	–	–
2	1.709	1.757	1.210	0.550	0.955	1.596	0.929	1.117	1.211	1.593
3	1.264	0.981	1.167	1.131	1.150	1.086	1.174	1.201	1.598	1.421
4	1.205	0.914	1.167	1.079	1.097	1.000	0.930	1.033	1.226	1.142
5	1.000	1.000	1.045	1.199	1.000	1.021	0.931	1.014	1.000	1.000
6	1.141	1.037	1.000	1.000	0.838	1.118	1.000	1.000	1.086	1.033
7	1.173	0.890	1.051	0.860	0.943	1.686	1.241	1.322	1.168	1.364
8	0.810	2.132	1.877	0.919	1.005	1.504	1.441	1.090	3.007	0.601
9	5.047	1.155	2.568	1.862	2.735	–	0.989	1.780	–	–

Score: 1 = extremely below average; 2 = well below average; 3 = below average; 4 = slightly below average; 5 = average; 6 = slightly above average; 7 = above average; 8 = well above average; 9 = extremely above average

CL = central ligament; FUA = fore udder attachment; FTP = front teat placement; FUL = fore udder length; RTA = rear teat attitude; RTP = rear teat placement; RUL = rear udder length; TL = teat length; TT = teat thickness; UD = udder depth

https://doi.org/10.17221/102/2021-CJAS

CONCLUSION

Linear type traits associated with the mammary system and feet and legs traits were suitable for indirect evaluation. This analysis showed that smaller and longer cows, with wider rump and deeper bodies, with normal hock angularity and slight elastic pastern, achieved a longer productive life. A well-formed udder reduced the rate of voluntary culling of animals and thus also contributed to increased longevity of cows.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

Berry DP, Harris BL, Winkelman AM, Montgomerie W. Phenotypic associations between traits other than production and longevity in New Zealand dairy cattle. J Dairy Sci. 2005 Aug 1;88(8):2962-74.

Bouska J, Vacek M, Stipkova M, Nemec A. The relationship between linear type traits and stayability of Czech Fleckvieh cows. Czech J Anim Sci. 2006;51(7):299-304.

Caraviello DZ, Weigel KA, Gianola D. Analysis of the relationship between type traits, inbreeding and functional survival in Jersey Cattle using a Weibull proportional hazards model. J Dairy Sci. 2003 Sep;86(9):2984-9.

Daliri Z, Hafezian SH, Shad Parvar A, Rahimi G. Genetic relationships among longevity, milk production and linear type traits in Iranian Holstein cattle. J Anim Vet Adv. 2008 Apr 1;7(4):512-5.

Ducrocq V, Quaas RL, Pollak EJ, Casella G. Length of productive life of dairy cows, justification of a Weibull model. J Dairy Sci. 1988 Nov;71(11):3061-70.

Famula TR. Exponential stayability model with censoring and covariates. J Dairy Sci. 1981 Mar 1;64(3):538-45.

Meszaros G, Solkner J, Ducrocq V. The Survival Kit: Software to analyze survival data includingpossibly correlated random effects. Comput Meth Programs Biomed. 2013 Jun 1;110(3):503-10.

Miglior F, Muir BL, Van Doormal BJ. Selection indices in Holstein cattle of various countries. J Dairy Sci. 2005 Mar 1;88(3):1255-63.

Novotny L, Frelich J, Beran J, Zavadilova L. Genetic relationship between type traits, number of lactations initiated, and lifetime milk performance in Czech Fleckvieh cattle. Czech J Anim Sci. 2017 Nov 2;62(12):501-10.

Pantelic V, Samolovac L, Aleksic S, Trivunovic S, Petrovic MM, Ostojic-Andric D, Novakovic Z. Heritability of type traits in first calving Black and White cows. Arch Tierz. 2010 Oct 10;53(5):545-54.

Samore AB, Rizzi R, Rossoni A, Bagnato A. Genetic parameters for functional longevity, type traits, somatic cell scores, milk flow and production in the Italian Brown Swiss. Ital J Anim Sci. 2010 Jan 1;9(2):145-52.

Schneider MD, Durr JW, Cue RI, Monardes HG. Impact of type traits on functional herd life of Quebec Holsteins assessed by survival analysis. J Dairy Sci. 2003 Dec 1; 86(12):4083-9.

Setati MM, Norris D, Banga CB, Benyi K. Relationships between longevity and linear type in Holstein cattle population of Southern Africa. Trop Anim Health Prod. 2004 Nov;36(8):807-14.

Sewalem A, Kistemaker GJ, Van Doormaal BJ. Relationship between type traits and longevity in Canadian Jerseys and Ayrshires using a Weibull proportional hazards model. J Dairy Sci. 2005 Apr 1;88(4):1552-60.

Sewalem A, Miglior F, Kistemaker GJ, Sullivan P, Van Doormal BJ. Relationship between reproduction traits and functional longevity in Canadian dairy cattle. J Dairy Sci. 2008 Apr 1;91(4):1660-8.

Tanzler J, Luntz B, Kucera J, Rohrmoser G. Fleckscore. Linear breeding description for Simmental [Internet]. Wienna, Austria: AGÖF; 2015 Nov. Available from: https://www.fleckscore.com/en/home/.

Vacek M, Stipkova M, Nemcova E, Bouska J. Relationships between conformation traits and longevity of Holstein cows in the Czech Republic. Czech J Anim Sci. 2006 Aug; 51(8):327-33.

Vukasinovic N, Moll J, Casanova L. Implementation of a routine genetic evaluation for longevity based on survival analysis techniques in dairy cattle populations in Switzerland. J Dairy Sci. 2001 Sep 1;84(9):2073-80.

Yerex RP, Young CW, Donker JD, Marx GD. Effects of selection for body size on feed efficiency and size of Holsteins. J Dairy Sci. 1988 May 1;71(5):1355-60.

Zavadilova L, Stipkova M, Nemcova E, Bouska J, Matejickova J. Analysis of the phenotypic relationships between type traits and functional survival in Czech Fleckvieh cows. Czech J Anim Sci. 2009 Dec 25;54(12):521-31.

Zavadilova L, Nemcova E, Stipkova M. Effect of type traits on functional longevity of Czech Holstein cows estimated from a Cox proportional hazards model. J Dairy Sci. 2011 Aug 1;94(8):4090-9.

Received: June 9, 2021
Accepted: November 18, 2021
Published online: December 1, 2021