Potential use of parameters of the milk flow curve for genetic evaluation of milkability

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Abstract

Starting in October 1998, a new milkmeter (LactoCorder) for dairy recording was introduced in Bavaria, Germany. With the LactoCorder milk yield is recorded but information is also available on milk flow. Based on thresholds of the flow rate, parameters are defined, e.g., maximum flow rate and duration of maximum flow rate. The LactoCorder is used on farms participating in test plans with alternate milk recording and sampling (AT), and on farms with milk recorded twice a day and alternate sampling (ATM), respectively, resulting in approximately 65% of the recorded cows having results obtained with the LactoCorder. A research project was initiated to implement a genetic evaluation for milkability, making use of the detailed information now available on milk flow curves. Since genetic relationships between udder health and milkability are well known, ongoing research is also focusing on this topic. For these analyses, information on somatic cell count will be added. Parameters of the milk flow curve included in a genetic evaluation will have to be selected with regard to milkability as well as to udder health. In analyses fixed effects of herd test day, lactation, days in milk, age at calving, time of milking, and bimodality of the flow curve were found to be highly significant for most of the traits.

1. Introduction

Milkability can be considered an important functional trait in dairy cattle with regard to udder health as well as to labour efficiency. A cow should be milked gently, quickly and completely, with no need for further adjustment of the milking unit and no need for machine stripping (Mein, 1998). However, there is evidence that faster milking cows have higher infection risk for mastitis (Grindal and Hillerton, 1991). In recent studies, genetic correlations between subjectively scored milkability and somatic cell score (SCS) in the first lactation was estimated to be 0.41 (Boettcher *et al*., 1998) and 0.44 (Rupp and Boichard, 1999), respectively. A smaller relationship was reported between milkability and clinical mastitis (CM). Luttinen and Juga (1997) found small negative values for the genetic correlation (-0.11 and –0.20) while the genetic correlation was positive (0.06) in Rupp and Boichard (1999).

Genetic evaluations for CM and SCS are implemented in several countries to improve udder health. Information on milkability is not used to select for mastitis resistance, even though De Jong and Lansbergen (1996) and Boettcher *et al.* (1998) proposed an udder health index that consisted of SCS, udder traits, and milking speed. In countries with genetic evaluation for milkability, e.g., Canada and Germany, the main objective of the evaluation is to improve labour efficiency.

In Bavaria (Southern Germany), average milk flow rate is used to describe milkability. It used to be recorded not on all cows but only on a sample of daughters of young sires, usually in the first part of the first lactation. Beginning in 1998, a new milkmeter for dairy recording was introduced in Bavaria. In addition to recording milk yield and taking component samples the LactoCorder (FossElectric) calculates milk flow rate during milking. For details see Worstorff et al. (1992). Milk flow rate is measured every 0.7 seconds, and an average of 4 measurements is stored every 2.8 seconds. The LactoCorder allows distinguishing between main milk yield and machine stripping yield. For management purposes, e.g., reduce over-milking, a chart of the milk flow curve can be printed on the farm directly after milking. In order to reduce the required storage capacity and to help describe the milk flow curve, a number of traits are derived from the curve based on threshold flow rates. From the beginning to the end of milking these traits are:

- Duration of increasing flow rate (**tIFR**): Period of time from a milk flow rate >0.5 kg/min to an incline of the milk flow curve < 0.8 kg/min^2
- Duration of peak flow rate (**tPFR**): Period of time between a sustained incline of the curve < 0.8 kg/min^2 and a sustained decline < 0.8 kg/min^2
- Duration of decreasing flow rate (**tDFR**): Period of time between the first sustained decline of the curve > 0.8 kg/min and a sustained milk flow rate < 0.2 kg/min
- Duration of over-milking (**tOM**): Period of time with a sustained flow rate < 0.2 kg/min
- Duration of machine stripping (**tMS**): Period of time where the sustained flow rate is > 0.2 kg/min

These traits cover all the phases of a milking which are generally used to describe the characteristics of milkability. Duration of main milking (**tMM**) is defined as the sum of tIFR, tPFR and tDFR. Average flow rate (**AFR**) now is calculated from tMM and the milk yield (**MY**) in this period, i.e., it is not comparable with the average flow rate recorded in the past because machine stripping yield (**MSY**) is not considered. Maximum flow rate (**MFR**) is the largest milk flow rate during the milking over a period of 8 measurements (~22 sec.). Additionally, the milkmeter records if the milk flow curve shows bimodality (**B**; 0/1) which is defined as a sudden and heavy drop of the flow rate shortly after milking begins. A bimodal milk flow curve usually indicates an inadequate stimulus resulting in a delayed let-down.

The LactoCorder is used in herds participating in dairy recording test plan AT (a.m.-p.m. recording). Producers are also offered a new test plan based on AT which mixes supervised and unsupervised testing. This test plan is called ATM where on one milking per test day the LactoCorder is operated by the producer. The LactoCorder was not introduced at the same time in all regions of Bavaria but successively. It was available throughout Bavaria in July 1999. As of September 1999, 49.7% of the producers in Bavaria participated in test plans involving the LactoCorder (with 29.2% in AT and 20.5% in ATM, respectively). 32.6% of the producers participated in test plan A4, 17.2% in test plan AT with another milkmeter (Tru-Tester), and 0.5% in test plans with unsupervised recording. The percentage of producers that will eventually use the LactoCorder depends on how many will switch test plans. Participating in A4 is considerably more expensive and participating in AT with another milkmeter is slightly less expensive than test plans involving the LactoCorder.

According to Duda (1996), using average milk flow for selection on milkability mainly resulted in an increased maximum flow rate while other aspects of milkability were not sufficiently taken into account. Particularly the duration of decreasing milk flow is considered to be an important trait with respect to udder health (Göft *et al.*, 1994). If near the end of the milking the milk flow slows down slowly, the cow likely does not milk out evenly. Single quarters may over-milk which could result in more teat end abnormalities, and eventually in a higher risk for mastitis (Hamann, 1989).

In 1999, a research project was initiated to develop a genetic evaluation for milkability based on traits derived from the milk flow curve. The traits eventually selected from the large number of traits available are supposed to be relevant for udder health as well as for labour efficiency. In the first part of the research project focus was on determining the fixed effects that should be included in models to analyse these traits.

2. Materials and methods

Data for these analyses were provided by the Bavarian dairy recording organisation, LKV Bayern. Records were from October 1998 through June 1999, and the traits included were milk yield, machine stripping yield, MFR, tPFR, tDFR, AFR, bimodality, and somatic cell count. Information on bimodality was available only since March 1999. Cows in test plan ATM had 2 records per test day, one supervised and one unsupervised. However, somatic cell count was available only from supervised milking where component samples were taken. For the analyses the log-transformed somatic cell count, somatic cell score (SCS), was used (Ali and Shook, 1980). Additionally for each record it was indicated whether the LactoCorder had recorded a machine stripping yield (MS=1) or not (MS=0). Data were edited with respect to breed (Fleckvieh, Braunvieh, German Holsteins), parity (1,2,3), days in milk (6-305), and age at calving (depending on breed and lactation). These edits left 1,424,647 records from 256,667 cows in 13,127 herds.

Data statistics are given in Table 1. Differences in milk yield, machine stripping yield, SCS, and milkability traits could be observed across lactations as well as across breeds. As expected, milk yield was largest in Holstein, and in all breeds it increased from lactation 1 to lactation 3. Machine stripping yield and frequency of machine stripping increased across lactations. Frequency of bimodality, which was smallest in Braunvieh, remained nearly constant across lactations. Similar to milk yield, MFR, AFR, and SCS increased from first to third lactation, with Fleckvieh having the smallest and Holstein having the largest values. Duration of peak flow rate did not change across lactations for Fleckvieh but it decreased for Braunvieh and Holstein. Duration of decreasing flow rate increased across lactations for all breeds.

2.1 Fixed effects

The three breeds were analysed separately with fixed test-day models where the shape of the lactation curve was accounted for with 4 regression coefficients as in Ali and Schaeffer (1987). For SCS, a slightly different model (model 2) was applied than for the other traits. Time of milking was not included in the model for SCS because only one observation per test-day was available.

Model 1:

$$y_{ijkmn} = HTD_i + P_j + B_k + T_m + b_1(A) + b_2(D/c) + b_3(D/c)^2 + b_4 \ln(c/D) + b_5(\ln(c/D))^2 + e_{ijkmn}$$

Model 2:

$$y_{ijkm} = HTD_i + P_j + B_k + b_1(A) + b_2(D/c) + b_3(D/c)^2 + b_4 \ln(c/D) + b_5(\ln(c/D))^2 + e_{ijkm}$$

where y is a test day observation (MFR, AFR, tPFR, tDFR, MSY, SCS), HTD is a fixed effect of the herd test-day, P is a fixed effect of parity, B is a fixed effect of bimodality of the milk flow curve, T is a fixed effect of time of milking (a.m./p.m.), b_1 is a regression coefficient on age at calving (A), b_2 and b_3 are regression coefficients on linear and quadratic effects on D/c (D = days in milk; c=380), and b_4 and b_5 are regression coefficients on the linear and quadratic effects of ln(c/D). The models were analysed with the GLM procedure from the SAS package (SAS, 1990).

2.2 Phenotypic correlations

Model 2 from 2.1 was used to calculate phenotypic correlations between SCS, MFR, AFR, tPFR, and tDFR for the three breeds. Correlations from this multivariate analysis are adjusted for fixed effects.

2.3 Regression coefficients

Regression coefficients of SCS on milkability traits were calculated for Fleckvieh in separate analyses with the following model:

$y_{ijkm} = HTD_i + P_j + B_k + b_1(A) + b_2(D/c) + b_3(D/c)^2 + b_4\ln(c/D) + b_5(\ln(c/D))^2 + b_6(\mathbf{X})$ e_{ijkm}

where y is a SCS test day observation, HTD is a fixed effect of the herd test-day, P is a fixed effect of parity, B is a fixed effect of bimodality of the milk flow curve, T is a fixed effect of time of milking (a.m./p.m.), b_1 is a regression coefficient on age at calving (A), b_2 and b_3 are regression coefficients on linear and quadratic effects on D/c (D = days in milk; c=380), b_4 and b_5 are regression coefficients on the linear and quadratic effects of ln(c/D), and b_6 is a regression coefficient on **X** with **X** being MY, MFR, tPFR, tDFR, AFR, and MSY, respectively, in separate runs. Regression coefficients were also calculated with a similar model where all milkability traits were fitted as covariables:

$y_{ijkm} = HTD_i + P_j + B_k + b_1(A) + b_2(D/c) + b_3(D/c)^2 + b_4\ln(c/D) + b_5(\ln(c/D))^2 + b_6(MFR) + b_7(tPFR) + b_8(tDFR) + b_9(AFR) + e_{ijkm}$

3. Results and discussion

3.1 Fixed effects

Results from analyses with models 1 and 2 for Fleckvieh are presented in Table 2. Effects of herd test-day, parity, and time of milking on milkability traits and SCS were highly significant (p>0.001). Larger values for MFR, tPFR, tDFR, AFR, and MSY were found for a.m. milking than for p.m. milking. Similar results for the effect of time of milking were obtained when regression on milk yield was included in the model for MFR, AFR and MSY, while differences were smaller for tPFR and tDFR (results not presented). Duda (1996) considered milkability traits from a.m. milking and p.m. milking to be different traits, and correlations between milkings were from 0.53 for machine stripping yield to 0.99 for maximum flow rate.

Cows in lactation 1 had larger values for tPFR, and smaller values for MFR, tDFR, AFR, SCS, and MSY than cows in lactations 2 and 3. Differences between lactations were highly significant except for the difference between lactations 2 and 3 for AFR. However, for some traits differences were small between lactations 2 and 3, e.g., for MFR, tDFR, and MSY, while for other traits differences between lactations 1 and 2 were similar to those between lactations 2 and 3.

Effect of age at calving was highly significant for all traits except for AFR, and the effect of bimodality was highly significant on all traits except for MSY. Cows with a bimodal milk flow curve had a considerably larger MFR than cows with a milk flow curve that did not show a sudden drop. It could be argued that bimodality should not be included in the model for MFR. Bimodality may not cause a larger MFR, but rather a bimodal milk flow curve may be more likely with a large MFR. Bimodality can be described as a gap between the flow of the milk stored in the cistern (at the beginning of the milking) and the flow of the milk from the alveolus. This drop in the milk flow rate indicates that an inadequate stimulus is more likely to occur in cows with a large MFR where the milk from the cistern is removed quickly. Duration of peak flow rate and duration of decreasing flow rate were longer if milk flow was not interrupted, and AFR was larger. SCS seemed to be larger for cows with a bimodal milk flow curve.

Functions of days in milk and log of days in milk fitted as covariables were highly significant for MFR, tPFR, and SCS. However, for the other traits simpler models might be sufficient. For example, the model for AFR only needs to include a regression on the linear and quadratic effect on D/c.

The results for Braunvieh (Table 3) were similar to those for Fleckvieh. For some of the traits, linear and quadratic effects on the log of D/c were not significant. Compared to Fleckvieh, differences between lactations were larger for MFR, tPFR, AFR, and SCS. For tDFR, only the difference between lactations 1 and 2 was significant. AFR was larger when bimodality was observed, which was not the case for Fleckvieh.

For Holstein, age at calving was significant only for tPFR, tDFR, and MSY (Table 4). The difference for AFR between a.m. and p.m. milking was considerably larger than the difference for Fleckvieh and Braunvieh. Holsteins had larger differences between lactations for MFR and tPFR than the other breeds. Similar to Braunvieh, AFR was larger when the milk flow curve was bimodal.

3.2 Phenotypic correlations

The phenotypic correlations between milkability traits and SCS for Fleckvieh, Braunvieh, and Holstein presented in Table 5 were highly significant. Large positive correlations were found between MFR and AFR. The correlations between MFR and tPFR were large and negative, indicating that a shorter duration of peak flow rate is needed to remove the milk if the maximum flow rate is large. For the same reason similar correlations could be expected between MFR and tDFR, but those were relatively small. However, correlations between AFR and tPFR were negative and in the same range as the correlations between AFR and tDFR. Small correlations were found between SCS and the milkability traits. MFR and tDFR were positively correlated with SCS. The negative correlation between tPFR and SCS may be due to the fact that the model accounted for days in milk but did not completely remove the effect of milk yield. A larger tPFR is very likely related with a higher milk yield. When a regression on milk yield was additionally included in the model the correlation between tPFR and SCS was slightly smaller (-0.12). According to Mrode and Swanson (1996) estimates from the literature for the phenotypic correlation between milk yield and SCS ranged from –0.01 to –0.10 (in the first lactation). However, estimates of the genetic correlation between milk yield and SCS were negative (e.g., Pösö and Mäntysaari, 1996; Luttinen and Juga, 1997; Rupp and Boichard, 1999). All correlations were similar across breeds. Duda (1996) reported different correlations between SCS and milkability traits across breeds.

3.3 Regression coefficients

Regression coefficients of SCS on milkability traits (Table 6) agreed well with the phenotypic correlations (Table 5). SCS increased when MFR and tDFR increased, and SCS decreased with decreasing tPFR and AFR. Increasing milk yield resulted in decreasing SCS, which can be regarded as a dilution effect. However, SCS decreased as machine-stripping yield increased. This may indicate that producers are more carefully in their milking routine with cows that have a history of mastitis or that show signs of a beginning mastitis.

The regression coefficients from the regression analysis with all milkability traits included as covariables were considerably more negative for tPFR and AFR. By simultaneously adjusting for the other milkability traits SCS decreased with increasing tDFR whereas the simple regression coefficient was positive.

4. Conclusion

Data for the analyses were from the routine dairy recording with the LactoCorder. Results agreed with Göft *et al.* (1994) and Duda (1996) who used data from the LactoCorder test trial. The milk flow curve and traits derived from the milk flow curve may be able to describe milkability in more detail than average milk flow, the trait currently used for selection on milkability. Further research will focus on the estimation of genetic parameters for MFR, tPFR, tDFR and AFR, and the genetic correlations of these traits with SCS. Estimates of heritability from a small data set were 0.48 for MFR, 0.22 for tPFR, and 0.24 for tDFR (Duda, 1996). It needs to be analysed if milkability is affected by bimodality, and how frequency of machine stripping and machine stripping yield, respectively, are related to milkability and udder health.

References

Ali, A.K.A., Shook, G.E., 1980. An optimum transformation for somatic cell concentration in milk. J. Dairy Sci. 63, 487-490.

Ali, T.E., Schaeffer, L.R., 1987. Accounting for covariances among test day milk yields in dairy cows. Can. J. Anim. Sci., 67, 637-644.

Boettcher, P.J., Dekkers, J.C.M., Kolstad, B.W., 1998. Development of an udder health index for sire selection based on somatic cell score, udder conformation, and milking speed. J. Dairy Sci. 81, 1157-1168.

De Jong, G., Lansbergen, L.,1996. Udder health index: selection for mastitis resistance. Proceedings International Workshop Genetic Improvement of Functional Traits in cattle (GIFT) - Health, Uppsala, INTERBULL Bulletin 12: 42-47.

Duda, J., 1996. New prospects in sire evaluation for milkability. Proceedings International Workshop on Genetic Improvement of Functional Traits in cattle (GIFT) - Health. Uppsala. INTERBULL bulletin 15: 27-32.

Göft, H., Duda, J., Dethlefsen, A., Worstorff, H., 1994. Untersuchungen zur züchterischen Verwendung der Melkbarkeit beim Rind unter Berücksichtigung von Milchflusskurven. Züchtungskunde 66, 23-37.

Grindal, R.J., Hillerton, J.E., 1991. Influence of milk flow rate on new intramammary infection in dairy cows. J. Dairy Res. 58, 263-268.

Hamann, J., 1989. Maschineller Milchentzug und Mastitis. Enke Copythek, Stuttgart.

Luttinen, A., Juga, J., 1997. Genetic relationships between milk yield, somatic cell count, mastitis, milkability and leakage in Finnish dairy cattle populations. Proceedings International Workshop on Genetic Improvement of Functional Traits in cattle (GIFT) - Health. Uppsala. INTERBULL bulletin 15: 78-83.

Mein, G.A., 1999. Design of milk harvesting systems for cows producing 100 pounds of milk daily. National Mastitis Council. http://www.nmconline.org/articles/100lbcow.htm.

Mrode, R.A., Swanson, G.J.T., 1996. Genetic and statistical properties of somatic cell count and its suitability as an indirect means of reducing the incidence of mastitis in dairy cattle. Anim. Breed. Abstr. 64, 847-856.

Pösö, J., Mäntysaari, E.A., 1996. Relationships between clinical mastitis, somatic cell score, and production for the first three lactations of Finnish Ayrshire. J. Dairy Sci. 79, 1284-1291.

Rupp, R., Boichard, D., 1999. Genetic parameters for clinical mastitis, somatic cell score, production, udder type traits, and milking ease in first lactation Holsteins. J. Dairy Sci 82, 2198-2204.

Statistical Analysis System (SAS), 1990. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2. SAS Institute., Cary, NC, USA.

Worstorff, H., Göft, H., Zierer, E., 1992. Milchflusskurven in der Leistungsprüfung. Pages 63-71 *in* Proc. Symp. Int. Komitee f. Leistungsprüfungen in der Tierproduktion (IKTL/ICAR), Neustift, Austria. EAAP Publication N0. 61.

Table 1. **Numbers of animals, numbers of observations, means and standard deviations for milk yield, milkability traits and SCS by breed and lactation**

Lactation	*Trait*	Fleckvieh				Braunvieh				Holstein			
		No. of animals	*No.of records*	$\bar{x}$	s	No. of animals	*No.of records*	$\bar{x}$	s	No. of animals	No. of records	$\bar{x}$	s
1	MY (kg)	123578	640079	9.01	2.54	23386	107796	9.49	2.50	7014	32654	11.04	3.09
	MFR (kg/min)	123578	640079	2.39	0.73	23386	107796	2.62	0.80	7014	32654	2.94	0.92
	TPFR (min)	123578	640079	2.72	1.61	23386	107796	2.60	1.60	7014	32654	2.64	1.67
	TDFR (min)	123578	640079	2.14	1.21	23386	107796	2.16	1.19	7014	32654	2.38	1.31
	AFR (kg/min)	123578	640079	1.66	0.49	23386	107796	1.83	0.52	7014	32654	2.01	0.59
	B (%)	100075	356895	25	43	19412	64421	15	36	5894	19744	21	41
	MS (%)	123578	640079	36	48	23386	107796	43	50	7014	32654	36	48
	MSY (kg)	123578	640079	0.12	0.29	23386	107796	0.14	0.30	7014	32654	0.11	0.32
	SCS	120820	366277	1.92	1.53	23080	73795	2.23	1.49	6834	20886	2.46	1.57
2	MY (kg)	89677	462461	10.06	3.40	17766	79323	10.48	3.42	5759	26386	12.08	4.18
	MFR (kg/min)	89677	462461	2.53	0.82	17766	79323	2.96	0.91	5759	26386	3.34	1.03
	TPFR (min)	89677	462461	2.70	1.75	17766	79323	2.27	1.55	5759	26386	2.22	1.60
	TDFR (min)	89677	462461	2.51	1.42	17766	79323	2.40	1.27	5759	26386	2.66	1.36
	AFR (kg/min)	89677	462461	1.70	0.54	17766	79323	1.98	0.59	5759	26386	2.17	0.65
	B (%)	72450	255913	26	44	14520	46183	17	38	4695	15324	24	43
	MS (%)	89677	462461	49	50	17766	79323	56	50	5759	26386	50	50
	MSY (kg)	89677	462461	0.24	0.44	17766	79323	0.24	0.43	5759	26386	0.20	0.39
	SCS	87512	265298	2.31	1.60	17536	54094	2.74	1.53	5622	16870	2.99	1.64
3	MY (kg)	63825	322107	10.48	3.61	12652	54893	11.22	3.72	3976	18216	12.84	4.46
	MFR (kg/min)	63825	322107	2.56	0.85	12652	54893	3.13	0.95	3976	18216	3.44	1.05
	TPFR (min)	63825	322107	2.71	1.79	12652	54893	2.19	1.53	3976	18216	2.22	1.61
	TDFR (min)	63825	322107	2.71	1.53	12652	54893	2.61	1.38	3976	18216	2.93	1.48
	AFR (kg/min)	63825	322107	1.71	0.57	12652	54893	2.05	0.62	3976	18216	2.19	0.67
	B (%)	51826	180025	24	43	10305	32197	16	37	3380	11168	23	42
	MS (%)	63825	322107	54	50	12652	54893	62	49	3976	18216	55	50
	MSY (kg)	63825	322107	0.29	0.52	12652	54893	0.31	0.51	3976	18216	0.25	0.47
	SCS	62170	185425	2.56	1.65	12464	37167	2.98	1.55	3903	11615	3.15	1.69

Table 2. **Influence of fixed effects on milkability traits, SCS and machine stripping yield for Fleckvieh**

Trait	*Effect* Herd test-day	*Differences between LS means for parities*[i]	Bimodality (0-1)	Time of milking (a.m.-p.m.)	Age at calving	D/c	(D/c)[ii]	ln(c/D)	(ln(c/D))[ii]
MFR	***	P1-P2: -0.10*** P2-P3: -0.01*** P1-P3: -0.11***	-0.33***	0.03***	***	***	***	***	***
TPFR	***	P1-P2: 0.19*** P2-P3: 0.17*** P1-P3: 0.36***	0.87***	0.36***	***	***	***	***	***
tDFR	***	P1-P2: -0.21*** P2-P3: -0.02*** P1-P3: -0.23***	0.13***	0.14***	***	***	n.s.	***	***
AFR	***	P1-P2: -0.03*** P2-P3: 0.01 n.s. P1-P3: -0.02***	-0.06***	0.05***	n.s.	***	***	n.s.	n.s.
SCS	***	P1-P2: -0.28*** P2-P3: -0.21*** P1-P3: -0.48***	-0.05***	–[iii]	***	***	***	***	***
MSY[ii]	***	P1-P2: -0.10*** P2-P3: -0.04*** P1-P3: -0.14***	0.00	0.01***	***	***	*	***	n.s.

[i] Effect of parity was highly significant (p>0.001) for all traits

[ii] Milkings included only if a machine stripping yield was recorded

[iii] Effect of time of milking was not included in the model applied for SCS (model 2)

Table 3. Influence of fixed effects on milkability traits, SCS and machine stripping yield for Braunvieh

Trait	Effect								
	Herd test-day	*Differences between LS means for paritie*[i]	Bimodality (0-1)	Time of milking (a.m.-p.m.)	Age at calving	D/c	(D/c)[ii]	ln(c/D)	(ln(c/D))[ii]
MFR	***	P1-P2: -0.24*** P2-P3: -0.05*** P1-P3: -0.28***	0.28***	0.03***	***	***	*	***	*
TPFR	***	P1-P2: 0.43*** P2-P3: 0.20*** P1-P3: 0.63***	0.77***	0.26***	***	***	***	***	***
TDFR	***	P1-P2: -0.06*** P2-P3: 0.02 n.s. P1-P3: -0.04 n.s.	0.05***	0.10***	***	***	***.	***	n.s.
AFR	***	P1-P2: -0.10*** P2-P3: -0.01 n.s. P1-P3: -0.11***	0.01**	0.05***	***	***	***	n.s.	n.s.
SCS	***	P1-P2: -0.43*** P2-P3: -0.23*** P1-P3: -0.66***	-0.06***	–[iii]	***	***	***	n.s.	n.s.
MSY[ii]	***	P1-P2: -0.06*** P2-P3: -0.02*** P1-P3: -0.09***	-0.01**	0.01***	***	n.s.	***	n.s.	n.s.

[i] Effect of parity was highly significant (p>0.001) for all traits
[ii] Milkings included only if a machine stripping yield was recorded
[iii] Effect of time of milking was not included in the model applied for SCS (model 2)

Table 4. Influence of fixed effects on milkability traits, SCS and machine stripping yield for Holstein

Trait	*Effect* Herd test-day	*Differences between LS means for parities*[i]	Bimodality (0-1)	Time of milking (a.m.-p.m.)	Age at calving	D/c	(D/c)[ii]	ln(c/D)	(ln(c/D))[ii]
MFR	***	P1-P2: -0.39*** P2-P3: -0.09*** P1-P3: -0.48***	-0.34***	0.05***	n.s.	***	***	***	n.s.
TPFR	***	P1-P2: 0.57*** P2-P3: 0.25*** P1-P3: 0.82***	0.82***	0.33***	***	***	**	***	***
TDFR	***	P1-P2: -0.12*** P2-P3: -0.02 n.s. P1-P3: -0.15***	0.07***	0.18***	***	***	n.s.	n.s.	***
AFR	***	P1-P2: -0.12*** P2-P3: -0.03 n.s. P1-P3: -0.15***	0.07**	0.18***	n.s.	***	***.	***	n.s.
SCS	***	P1-P2: -0.45*** P2-P3: -0.26*** P1-P3: -0.71***	-0.09***	–[iii]	n.s.	***	***	***	***
MSY[ii]	***	P1-P2: -0.06*** P2-P3: -0.02*** P1-P3: -0.08***	0.00	0.01**	***	**	n.s.	n.s.	n.s.

[i] Effect of parity was highly significant (p>0.001) for all traits
[ii] Milkings included only if a machine stripping yield was recorded
[iii] Effect of time of milking was not included in the model applied for SCS (model 2)

Table 5. **Phenotypic correlations[i] between milkability traits and SCS by breed**

Trait	*Breed*	TPFR	TDFR	AFR	SCS
MFR	**FV**	-0.59	-0.12	0.84	0.05
	BV	-0.61	-0.12	0.82	0.05
	H	-0.59	-0.16	0.81	0.08
TPFR	FV		-0.20	-0.40	-0.15
	BV		-0.20	-0.40	-0.15
	H		-0.11	-0.39	-0.16
TDFR	FV			-0.43	0.03
	BV			-0.46	0.06
	H			-0.49	0.03
AFR	FV				-0.01
	BV				-0.02
	H				-0.01

[i] All correlations were highly significant (p > 0.001)

Table 6. **Regression coefficients of SCS on milkability traits, milk yield and machine stripping yield for Fleckvieh**

Trait	Regression coefficients[i,ii]	Regression coefficients[i,iii]
MFR	0.12	0.27
TPFR	-0.16	-0.75
TDFR	0.03	-0.11
AFR	-0.04	-0.75
Milk yield	-0.12	–
Machine stripping yield	0.17	–

[I] All regression coefficients were highly significant (p > 0.001)
[ii] Regression coefficients from separate runs with one milkability trait included
[iii] Regression coefficients from a model were all milkability traits were included