The relationship between somatic cell count, milk production and six linearly scored type traits in Holstein cows

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

Institute of Animal Science, Prague-Uhříněves, Czech Republic

ABSTRACT: Test-day records of somatic cell count (*SCC*), milk yield, fat and protein content and six linearly scored type traits (fore udder attachment, udder depth, central ligament, rear udder height, front teat placement, teat length) of 22 613 first lactation cows from 117 herds were included in this study. *SCC* was log-transformed into somatic cell score (*SCS*). Milk yield was standardized as follows: MILK = milk yield (fat content + protein content)/(3.8 + 3.2). For each analyzed type trait, cows were assigned to one of the three levels according to linear type score: level 1 (score 1 and 2); level 2 (score 5 and 6); level 3 (score 8 and 9). A linear model was used to estimate the effect of different type traits on MILK and *SCS*. The highest values of *SCS* were found for the first levels. The differences between the first and second level were on average 0.33, 0.54, 0.28, and 0.36 for fore udder attachment, udder depth, central ligament and rear udder height, respectively. The cows with deep udders, weak central ligaments and fore attachments and low rear udder height showed the highest *SCS*. Low *SCS* appeared to be associated with an intermediate distance between the front teats and longer teats. The third level of udder depth (shallow udder) had low MILK. Rear udder height showed low MILK for the first level (low height) with the highest MILK values for the third level (high height). The average difference was 3.3 kg.

Keywords: cattle; linear evaluation of type traits; somatic cell count; milk production

In most countries, dairy cattle breeding programmes are mainly aimed at milk production traits with increasing focus on conformation traits. Although these traits are of primary economic importance, functional traits such as longevity, fertility and udder health are of greater interest to producers to improve the herd profitability. Among others, an extreme emphasis on selection for milk yield may have negative effects on type traits that contribute to overall fitness. The objective of breeding systems is to maximize the overall herd profit (Krupa et al., 2005; Bouška et al., 2006b). Research in the area of cattle breeding is increasingly aimed at identifying new selection criteria which would contribute to the genetic improvement of economically important traits with low heritability (such as longevity or health traits). One of the possible solutions is to use indirect selection for these characteristics through selection of animal type traits (Bouška et al., 2006b).

As mentioned by Bouška et al. (2006a), changes in the definition of breeding goals in dairy cattle can be demonstrated by the development of selection indexes. The weights of different components (including functional traits) in total selection indexes as well as their sub-indexes were reported by Šafus et al. (2005).

Mastitis is the most costly disease in dairy cattle because of its high heritability, its biological effects and economic consequences, including the loss of milk production, increased culling rates and costs of veterinary treatment. From the aspect of mastitis, udder traits are the most important (Mrode and Swanson, 1996).

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Somatic cell count (*SCC*) is one of the most important and accurate measures of udder health. Results of numerous studies showed the existence of an evident genetic relationship between somatic cell count and type trait score, especially for the udder traits (Van Raden et al., 1990; Short et al., 1991; Misztal et al., 1992; Short and Lawlor, 1992; Rupp and Boichard, 1999; DeGroot et al., 2002). Type traits and *SCC* are currently recorded systematically in a large portion of the cattle population. There is a great potential for improving the udder health through selection for udder type traits, perhaps with *SCC*, particularly when higher *SCS* (a logarithmic transformation of *SCC*) is genetically associated with higher occurrence of clinical mastitis (Philipsson et al., 1995; Rogers et al., 1998; Nash et al., 2000, 2002).

A generally favourable (negative) genetic relationship has been found between some udder conformation traits and *SCC* (Seykora and McDaniel, 1986; Rogers et al., 1991; Rupp and Boichard, 1999; Kadarmideen, 2004), with an emphasis on udder depth and fore udder attachment. Genetic correlations indicated that cows with higher, more tightly attached udders and closer teats had lower *SCC*.

Reported environmental correlation estimates between these traits were usually low, close to zero (Rupp and Boichard, 1999). Phenotypic correlations between udder traits and *SCC* were found variable, generally lower than genetic correlations (Mrode and Swanson, 1996) showing the same trend.

On the other hand, unfavourable (positive) genetic correlations between milk production and *SCC* have been reported (Rupp and Boichard, 1999; Kadarmideen, 2004). In the literature some negative genetic estimates were published as well (Roman and Wilcox, 2000) even though the positive estimates of genetic correlations between milk production traits and *SCC* dominated (Mrode and Swanson, 1996). For daily measurements Haile-Mariam et al. (2001) found that the genetic correlation between milk yield traits and log *SCC* changed from low positive to negative during the first lactation. Environmental correlations were consistently negative if *SCC* and the traits were measured on the same day or on days close to each other in time.

Phenotypic correlations between milk production and *SCC* were much lower than genetic correlations but they had a similar positive direction of the relationship (Kadarmideen, 2004). In later parities the estimates of phenotypic correlations tended to be more negative than in the first parities (Mrode and Swanson, 1996).

Type traits genetically associated with *SCS* were reported by DeGroot et al. (2002). The traits affected to the greatest extent by divergent selection for predicted transmitting ability for type (PTAT) were fore udder attachment, rear udder height and width, central ligament, udder depth and front teat placement. DeGroot et al. (2002) concluded that selection for PTAT had a favourable effect on *SCS*. Similar conclusions were drawn by Kadarmideen (2004) on the basis of favourable genetic correlations between udder traits and *SCC*.

The objective of this study was to describe the relationship between udder conformation traits and somatic cell count in Czech Holstein cattle and to identify the traits suitable for selection for reducing the somatic cell count without negative effects on milk production.

MATERIAL AND METHODS

Monthly test-day observations of milk somatic cell count (*SCC*), milk yield, fat and protein content were recorded for primiparous Holstein cows calving between 1998 and 2006. The records included only herds that were completely recorded for *SCC* as well. Lactations with less than three records of monthly yield tests were discarded. Type classification records were obtained from the Czech-Moravian Breeders' Association (CMBA). Type traits of daughters of sires were evaluated by CMBA classifiers using the linear system of conformation evaluation. Six linearly scored type traits (fore udder attachment, udder depth, central ligament, rear udder height, front teat placement and teat length) were included in the study. Data were edited to include only cows classified between the 30^{th} and 210^{th} day of the first lactation. The final dataset included first lactation records and type classification from 22 613 cows in 117 herds. The dataset was completed by the age of the cows and pedigree information.

The monthly test-day observation of *SCC* was log-transformed into the monthly test-day observation (*SCS*) as $SCS = \log_{10} SCC$ (Mrode and Swanson, 1996).

The test-day milk production records were transformed into milk yield with standardized fat and protein content in order to correct for differences in milk components:

MILK = milk yield (fat content + protein content)/(3.8 + 3.2).

To emphasize the tendencies between type traits and somatic cell score and based on the method described by Bouška et al. (2006a), the cows were assigned to one of the three levels for each analyzed type trait: level 1 (score 1 and 2) representing the lower extreme; level 2 (score 5 or 6) representing the mean value; level 3 (score 8 and 9) representing the upper extreme. Cows' classification for those traits that did not match any of the above-mentioned levels was discarded from the evaluation. The following scale was used for the linear evaluation of selected type trait (rated from 1 to 9):

fore udder attachment – weak and loose to extremely strong and tight

udder depth – below hock to shallow

central ligament – convex to flat floor to deep definition

rear udder height – very low to high

front teat placement – outside of quarter to inside of quarter

teat length – short to long.

The effects of linear evaluation of the particular type traits on MILK and *SCS* were determined on the basis of the following linear model:

$$y_{ijklm} = \mu + S_i + R_j + O_k + H_l + \beta\nu + e_{ijklm}$$

where:

y_{ijklm} = the test-day record of MILK or *SCS*
S_i = fixed effects of the i^{th} herd of calving
R_j = fixed effects of the j^{th} year of calving
O_k = fixed effects of the k^{th} season of calving
H_l = fixed effects of the l^{th} group of the analyzed type trait
$\beta\nu$ = fixed linear regression on the age at calving
e_{ijklm} = the residuum

The analyses were performed using the ordinary least squares methods in the GLM procedure of statistical software SAS® (SAS, 2001).

RESULTS AND DISCUSSION

All the analyzed linearly evaluated type traits (Table 1) had a significant effect on MILK and on *SCS* during the entire lactation with the exception of fore udder attachment and teat length. Fore udder attachment showed a statistical influence on MILK only in the first two test days of lactation. Teat length showed a lower statistically significant influence on MILK in the last part of lactation and a significant influence on *SCS* only at the beginning and in the middle of lactation. Front teat placement had no significant influence on MILK in the first test day in lactation and on *SCS* in the last test day in lactation.

The estimated least squares means for levels of the particular type traits were plotted to identify trends for each trait (MILK, *SCS*). The results are presented in Figures 1 to 12.

For *SCS* (Figures 1 to 6) the highest values of *SCS* occurred mainly at the first level of the type trait. Subsequently the first level of particular traits was significantly different from the second and third level for the majority of the analyses.

Table 1. Statistical significance of *F*-test for the analysed type traits

Lactation month	Fore udder attachment		Front teat placement		Teat length		Udder depth		Rear udder height		Central ligament	
	MILK	*SCS*	MILK	*SCS*	MILK	*SCS*	MILK	*SCS*	MILK	*SCS*	MILK	*SCS*
1	***	***	–	*	*	–	***	***	***	***	**	***
2	*	***	**	***	***	*	***	***	***	***	***	***
3	–	***	***	***	***	*	***	***	***	***	***	***
4	–	***	***	***	***	**	***	***	***	***	***	***
5	–	***	***	***	***	–	***	***	***	***	***	***
6	–	***	***	***	**	**	***	***	***	***	***	***
7	–	***	**	*	***	–	***	***	***	***	***	***
8	–	***	***	*	*	–	***	***	***	***	***	***
9	–	***	***	**	–	–	***	***	***	**	***	*
10	–	***	*	–	*	–	***	***	***	**	*	*

$P > 0.05$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

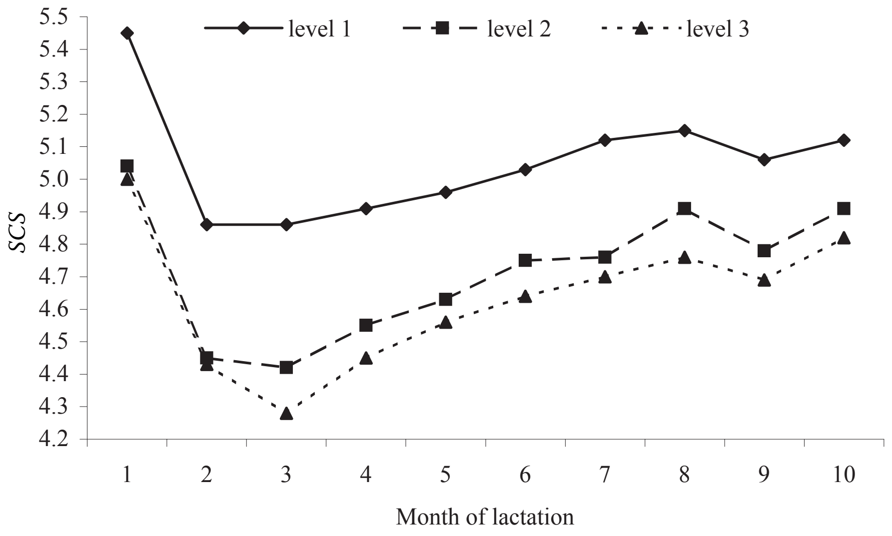


Figure 1. Least squares means of *SCS* for different levels of fore udder attachment during lactation

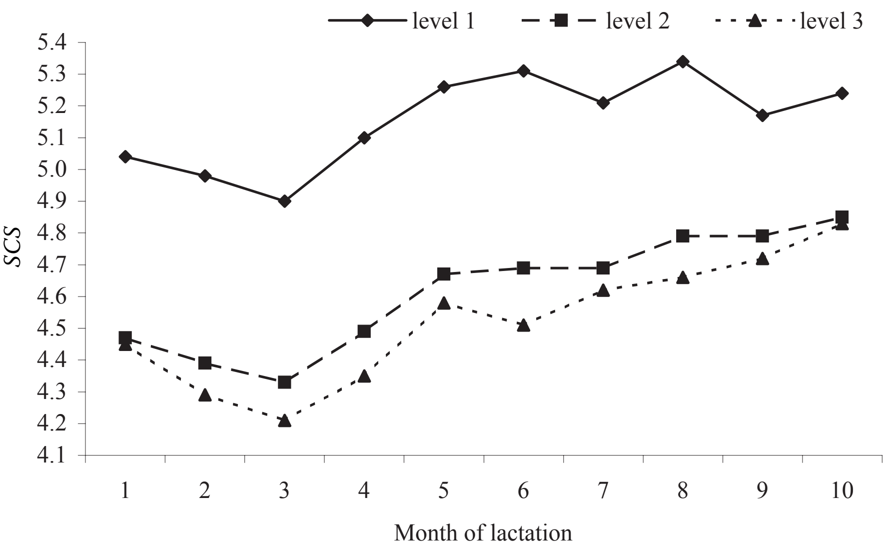


Figure 2. Least squares means of *SCS* for different levels of udder depth during lactation

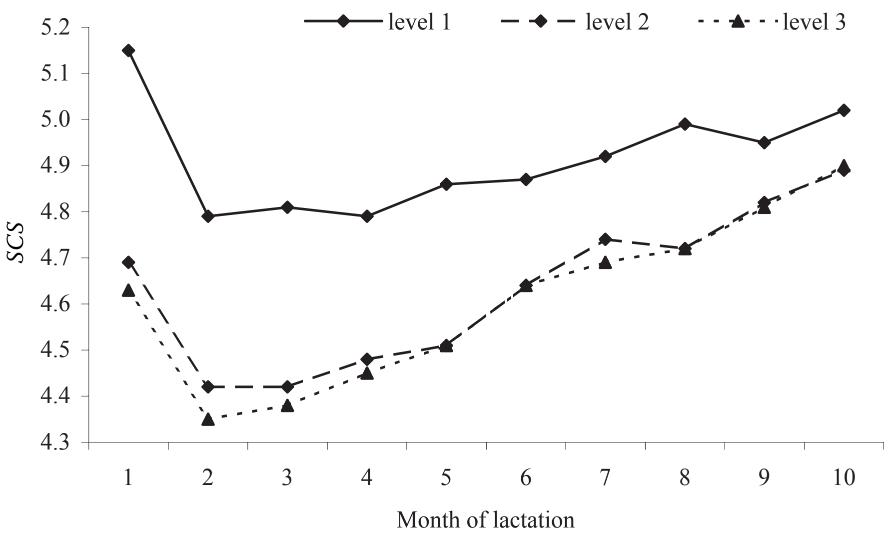


Figure 3. Least squares means of *SCS* for different levels of central ligament during lactation

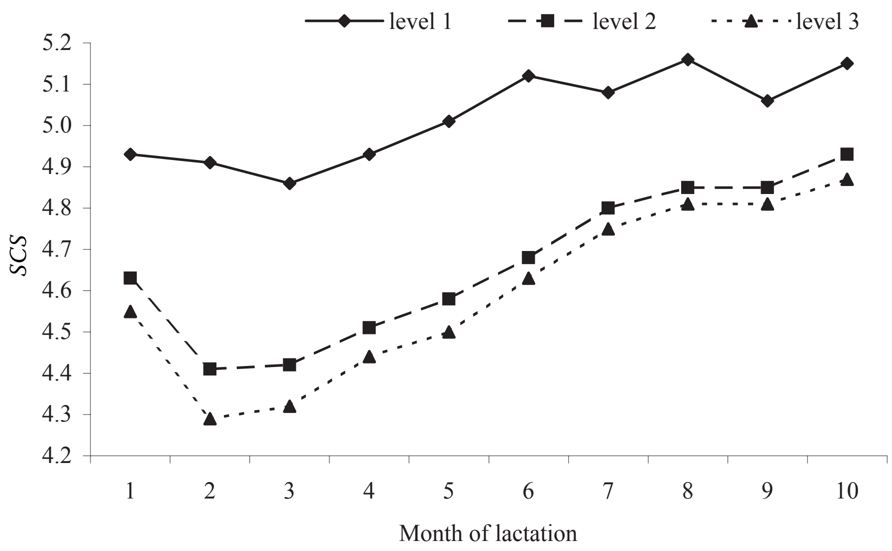


Figure 4. Least squares means of *SCS* for different levels of rear udder height during lactation

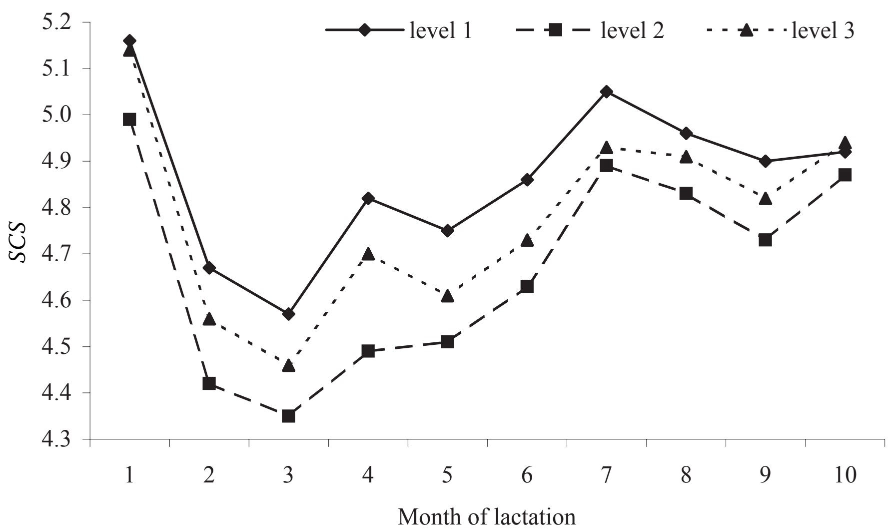


Figure 5. Least squares means of *SCS* for different levels of front teat placement during lactation

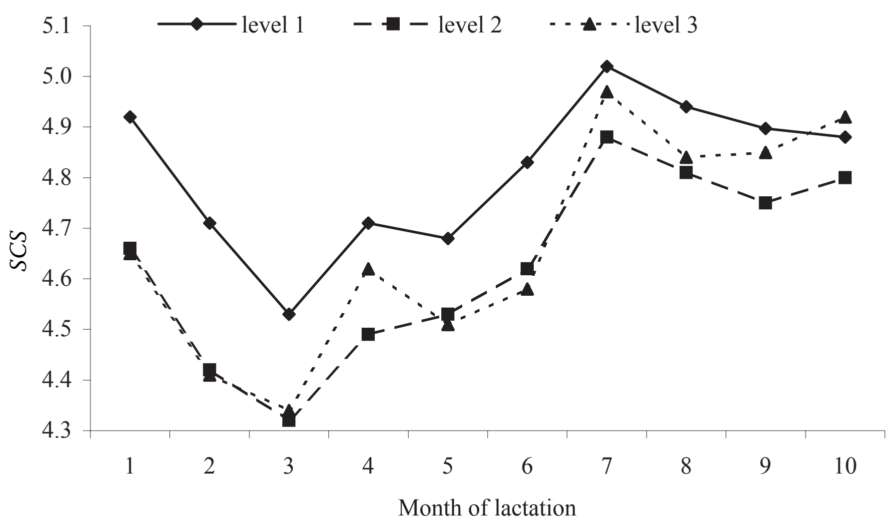


Figure 6. Least squares means of *SCS* for different levels of teat length during lactation

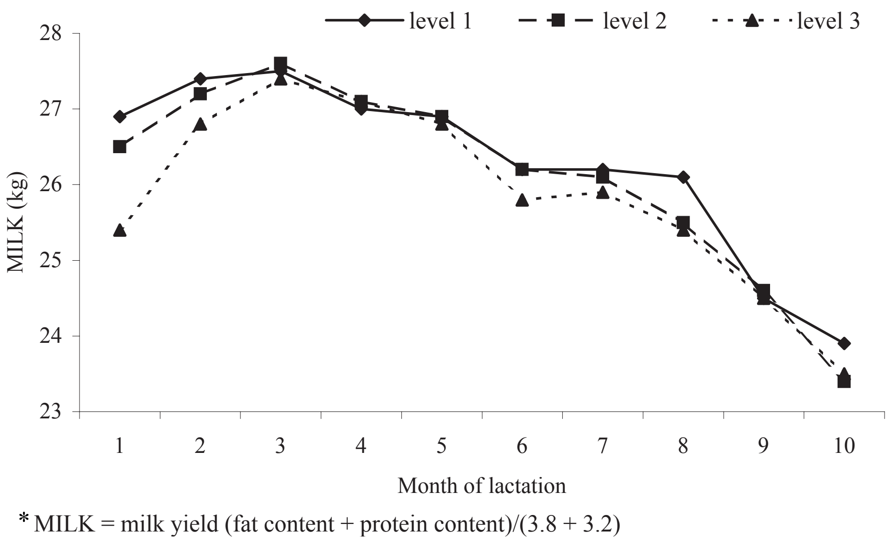


Figure 7. Least squares means of *MILK for different levels of udder attachment during lactation

Fore udder attachment (Figure 1) showed the highest value of *SCS* for the first level, weakly attached udders. *SCS* for the second and third level were substantially lower, with the lowest values for the third level.

Similar tendencies were found for udder depth (Figure 2). The highest *SCS* was at the first level, i.e. deep udders. Both further levels showed much lower *SCS*, the lowest being for the third level.

Central ligament (Figure 3) also showed the highest *SCS* for the first level, i.e. cows with convex udders. The second and third level had the same values of *SCS*, considerably lower than the first level.

For rear udder height (Figure 4) graphical analysis confirmed the highest values for the first level, a very low manifestation of the trait. Much lower *SCS* was found at the second and third level. High rear udder height, i.e. the third level, had the lowest values of *SCS*. The difference between the first level and the second level was on average 0.33; 0.54; 0.28; 0.36 for fore udder attachment, udder depth, central ligament and rear udder height, respectively.

While the above-mentioned traits showed similar trends for *SCS*, the next two traits, front teat placement and teat length, showed a different tendency. For front teat placement (Figure 5) the analysis showed the highest *SCS* for the first level; teats outside of the quarter, the middle *SCS*; and for the third level, teats inside the quarter. The lowest *SCS* was found for the second level, teats in the middle of the quarter. The differences between levels were on average 0.10.

The highest *SCS* related to teat length (Figure 6) was at the first level, short teats. The *SCS* for the second and third level were lower. Even though both levels showed similar values, the second level had

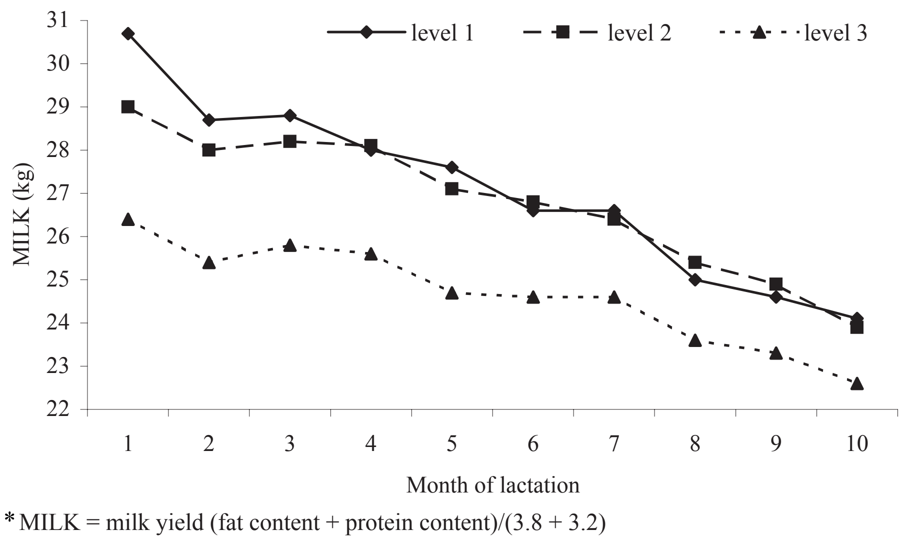


Figure 8. Least squares means of *MILK for different levels of udder depth during lactation

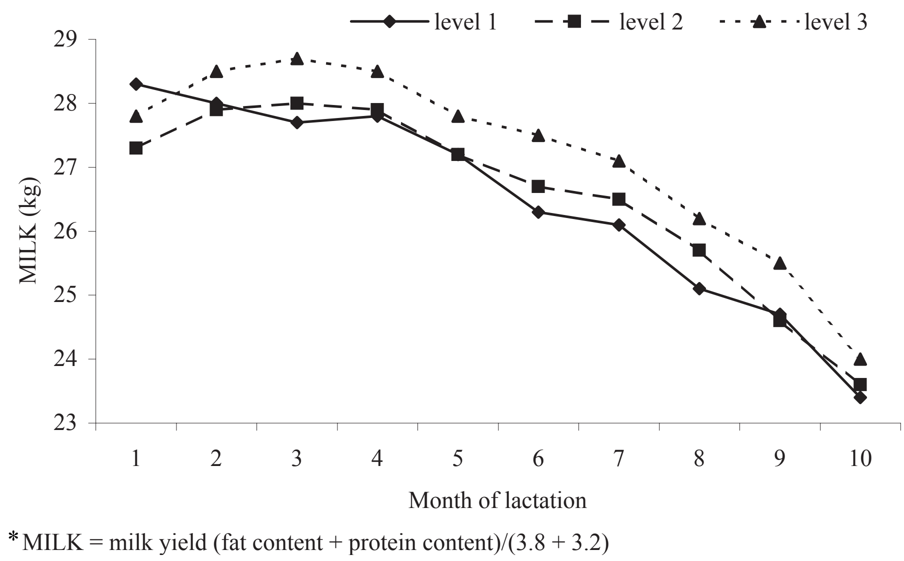


Figure 9. Least squares means of *MILK for different levels of central ligament during lactation

lower values of *SCS*. The difference between the first level and the second level was on average 0.18.

Based on the presented results, we can conclude that the cows with deep udders, weak central ligaments and fore attachments and low rear udder heights showed the highest *SCS*. This is consistent with the results of Seykora and McDaniel (1986), who reported lower *SCS* for cows with higher udders and deeper central ligament. Mrode and Swanson (1996) mentioned that phenotypic correlations between *SCC* and udder traits had generally been lower than genetic correlations, but they confirmed the same relationships. Studying genetic correlations, Boettcher et al. (1998) and Rupp and Boichard (1999) found deep udders and weak fore udder attachment associated with increased *SCS*. Similarly, Rogers et al. (1991), DeGroot et al. (2002) and Kadarmideen (2004) concluded that selection for higher udders with tighter attachments would be favourable for reducing *SCS*.

Higher *SCS* were determined in cows with larger as well as smaller distance between teats. In accordance with our findings, Seykora and McDaniel (1986) reported higher *SCS* for cows with smaller distances between teats, while DeGroot et al. (2002) preferred closer teats as favourable for selection for lower *SCS*. Similarly, Rogers et al. (1991) and Kadarmideen (2004) reported a negative genetic relationship between *SCS* and front teat placement.

The cows with shorter teats showed a higher value of *SCS*. On the contrary, Rogers et al. (1991) found a positive genetic correlation between teat length and *SCC*.

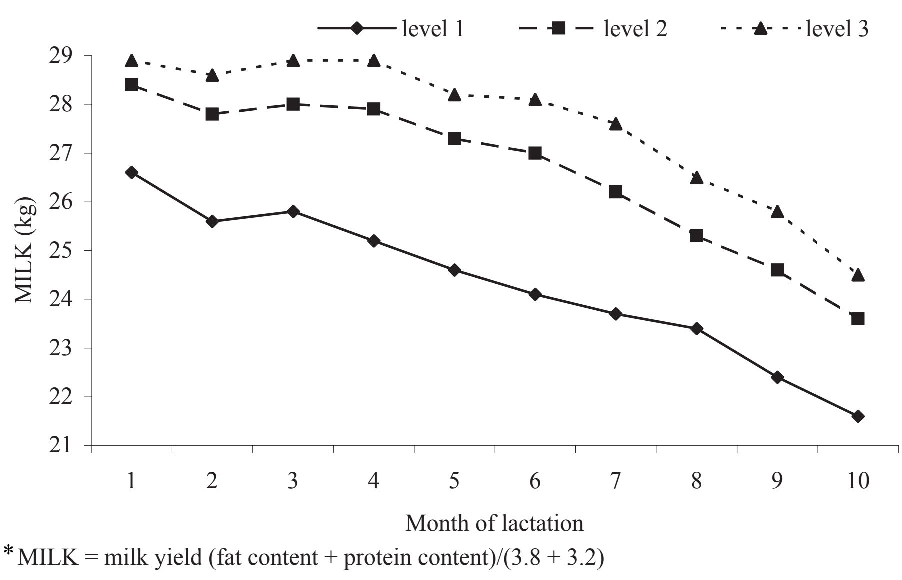


Figure 10. Least squares means of *MILK for different levels of rear udder height during lactation

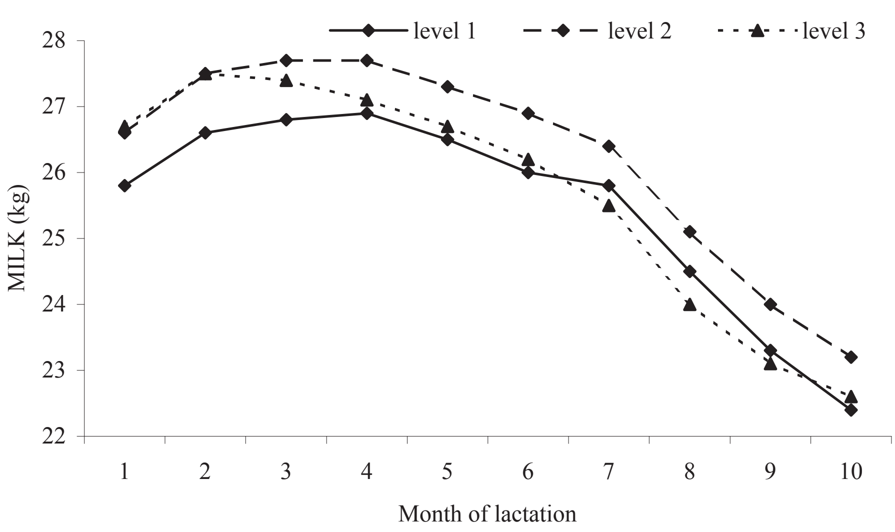


Figure 11. Least squares means of *MILK for different levels of front teat placement during lactation

*MILK = milk yield (fat content + protein content)/(3.8 + 3.2)

The analyses of MILK (milk yield corrected for fat and protein content) answered the question whether some of the desirable expressions of chosen type traits were connected with high or low milk production. For all type traits MILK values followed the general course of the lactation curve for milk yield.

Fore udder attachment (Figure 7) showed similar values of MILK for all three levels during the entire lactation.

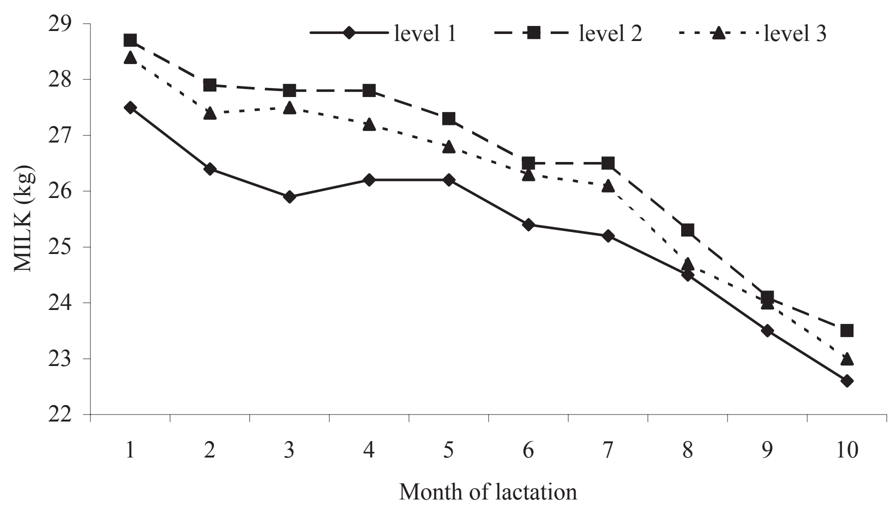
Udder depth (Figure 8) showed similar values of MILK for the first and second level. We found that the third level of udder depth (shallow udder) had a considerably lower value of MILK than the other levels. The average difference between the first and the third level was 2.41 kg of MILK.

Similar values of MILK for the first and second level and somewhat higher MILK values for the third level (deep) were found for central ligament (Figure 9).

Rear udder height (Figure 10) showed the lowest MILK for the first level (low height), the highest MILK values for the third level (high height), while the MILK for the second level occurred below the third level. An average difference between the third and the first level was 3.3 kg of MILK.

For teat placement (Figure 11) the highest milk production occurred at the second level of the trait. The first and the third level had lower values of MILK even though the third level showed higher values of MILK at the beginning of lactation. An average difference between the second and the third level was 0.56 kg of MILK.

A similar result was found for teat length (Figure 12). The highest value of MILK occurred at the second



*MILK = milk yield (fat content + protein content)/(3.8 + 3.2)

Figure 12. Least squares means of *MILK for different levels of teat length during lactation

level, followed by the third level. The first level was related to the lowest value of MILK. An average difference between the second and the first level was 0.8 kg of MILK while that between the second and the third level was 0.4 kg of MILK.

The findings referred to agree with the conclusions that fore udder attachment, udder cleft and udder depth have a negative association with milk yield whereas rear udder height has a positive correlation with milk production (Foster et al., 1989; Misztal et al., 1992; Short and Lawlor, 1992). DeGroot et al. (2002) concluded that traits related to udder attachment had a negative genetic relationship with milk yield, whereas udder capacity traits had a positive relationship. In full correspondence to the conclusion of DeGroot et al. (2002), higher values of MILK were found for high rear udder height (the third level) and weak central ligament, i.e. connection with large udders.

There was no marked deterioration of milk production connected with the second level of the analyzed udder traits with regard to lower *SCS*. According to their effects on MILK, the type traits could be divided into two groups. The first group includes teat length, teat placement and rear udder height. The cows of the second level showed higher MILK than those of the first level. The second group consists of fore udder attachment, central ligament and udder depth. The cows of the first level had the same MILK as those of the second level. There was no connection between *SCS* and MILK for the analyzed level of udder traits. Low or high milk production for the level of the udder traits can be better explained by udder conformation, i.e. a large udder equals high milk production.

CONCLUSION

We can conclude that the linear evaluation of chosen type traits (fore udder attachment, udder depth, central ligament, rear udder height, front teat placement and teat length) can be used as a positive criterion for the selection of cows with low somatic cell count for sufficient milk production. Cows with higher udders, deeper central ligaments, tighter attachments, centrally placed teats of middle length are the most desirable. The optimal value of udder traits was not connected with deterioration of milk production. Therefore, we can suggest the linear evaluation of type traits as auxiliary criteria for selection.

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Corresponding Author

Ing. Eva Němcová, Institute of Animal Science, Přátelství 815, 104 00 Prague-Uhříněves, Czech Republic
Tel. +420 267 009 587, fax +420 267 711 448, e-mail: nemcova.eva@vuzv.cz