Effect of Somatic Cell Score on Protein Yield in Holsteins

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ABSTRACT : The study was conducted to determine if variation in protein yield can be explained by expressions of early lactation somatic cell score (SCS) and if prediction can be improved by including SCS among the predictors. A data set was prepared (n=663,438) from Wisconsin Dairy Improvement Association (USA) records for protein yield with sample days near 20. Stepwise regression was used requiring F statistic ($p < .01$) for any variable to stay in the model. Separate analyses were run for 12 combinations of four seasons and first three parities. Selection of SCS variables was not consistent across seasons or lactations. Coefficients of determination (R^2) ranged from 51 to 61% with higher values for earlier lactations. Including any expression of SCS in the prediction equations improved R^2 by < 1%. SCS was associated with milk yield on the sample day, but the association was not strong enough to improve the prediction of future yield when other expressions of milk yield were in the model.

(Key Words: Somatic Cell Score, Protein Yield, Holsteins)

INTRODUCTION

Since the dawn of this century, dairy farmers have been encouraged to select cows for higher milk yield and fat contents as the milk payment system was based on volume and milk fat contents. In the last few decades however, more emphasis has been placed on the value of milk protein as its volume and composition is important to cheese manufacturer (Ng-kwai-hang et al., 1982). The other important development in the payment systems is the payment on the basis of milk hygiene. Somatic cells are used as an indicator of udder health and with the advent of electronic somatic cell counting, somatic cell counts (SCC), are now routinly recorded for million of cows. As a marker trait for mastitis resistence, they are also being included in the sire summaries for genetic selection purposes (Schutz, 1994; Shook and Schutz, 1994).

Somatic or body cells in milk are of two types, sloughed epithelial cells from the udder and leukocytes from the blood. The epithelial cells are present in normal milk as a normal breakdown and repair while leukocytes enter milk from blood, being attracted by chemical substances released from injured mammary tissue. Because the lactating mammary gland is a very active metabolic organ, it is logical to expect variation in cell counts from day to day or milking to milking. However, there is good agreement in the literature that the major factor responsible for elevation of somatic cells in milk is the presence of microorganisms (Schultz, 1977).

Relationship between SCC and milk production has been well documented (Raubertas and Shook, 1982; Emanuelson and Funke, 1991; Miller et al., 1993; Nielen et al., 1993). Many authors have shown that somatic cells can be used to explain variation in lactation milk yield. Raubertas and Shook (1982) reported that linear regression of 305-day lactation milk yield on average $\log_e$ SCS of lactation was -135 kg for first parity and on the average -270 kg for later parities. Also, a unit increase in the lactation average $\log_e$ SCC was associated with a loss of approximately 296 kg of milk per lactation in the study of Fetrow et al. (1991). Appleman et al. (1985) used six management traits to explain variation in herd average production. Sixteen percent of the variation was explained by SCC alone. SCC was the most important management trait in large herds (> 80 cows) and low producing herds (< 6311 kg).

Similar association between cell counts and test-day milk yield has been reported to exist (Jones et al., 1984; Batra, 1986, Sender et al., 1992; Miller et al., 1993; Nielen et al., 1993; Khan et al., 1994; Miller et al., 1996). Cell counts were negatively correlated with milk yield and accounted for 17% and 23% of the variation in milk yield in the studies of Nielen et al. (1993) and Sender et al. (1992). Quarter foremilk SCC was reported to be

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slightly more useful in predicting milk yield than bucket SCC in the study of Miller et al. (1993). Within-cow regression of milk yield on SCS ranged from −5.2 to −6.3 kg. Although, most of these studies explain the relationship of somatic cells with milk yield, potential usefulness of SCS for improving accuracy of yield projections has not been explored.

Incomplete lactation records are normally extended to a 305-day basis for herd management as well as genetic evaluations of cows and bulls. Yields are usually recorded monthly and 305-day lactation yield is calculated by linear interpolation between monthly weights. The current method used by United States Department of Agriculture (USDA) for projecting 305-day milk yield from partial performance involves regressing average daily yield in the later stages of lactation on measures of yield in early lactation (Wiggans and Dickinson, 1985). Predictors include days in milk (DIM) for the partial record, herd average milk yield (mature equivalent), and last test day yield (BASE variables). Predictions are comparatively poorer for the start and the end of the lactation period. The purpose of this study was to examine whether variation in protein yield can be explained by early lactation SCS and if prediction of future yield within parity can be improved by including SCS variables among predictors.

MATERIALS AND METHODS

Lactation records, including test-day records of milk and protein yield and somatic cell count (SCC) of Holstein cows calving between 1988 and 1992 were used. Data were from herds that participated in the Wisconsin Dairy Herd Improvement (DHI) program. Lactations were required to be at least 275 days in length and have at least nine sample days, of which at least one was after 250 days in milk (DIM). Cows were required to be on an official test plan and had sire identification. Only records from first, second and third parities were kept. Age at calving within lactation was limited to 18 to 36, 30 to 54 and 42 to 72 months for the three parities.

A data set for protein yield near sample day 20 was created. Sample DIM were restricted between 7 to 35 for samples to be near day 20. Lactations with less than 305-days in length but more than 275 days were extended to 305-days (Wiggans, 1985). Yields for partial records were obtained from test interval yields as described by Wiggans (1985). Limitations imposed on the production variables were: 305 day milk yield (M305), 2,270-15,000 kg; 305-day protein yield (P305), 68-454 kg; and protein yield of sample near day 20 (P20), 0.23-2.27 kg. Somatic cell scores (SCS) were obtained by transforming test-day somatic cell counts to the $\log_2$ scale (Ali and Shook, 1980). Herd average 305-day ME milk and protein yields, and herd average SCS were calculated within years. Four seasons were defined as winter (December-February), spring (March-May), summer (June-August) and fall (September-November).

The model used by USDA for projecting milk yield records of less than 305 days to 305 days was employed. The procedure is based on the number of days the cow actually milked, plus an estimate for the remainder of the 305-day lactation computed from the last available sample-day yield (Wiggans and Dickinson, 1985). It can be represented as:

$$\hat{Y}_{305} = Y_{DIM} + (\hat{Y}_D)\,(305\text{-DIM})$$

where $\hat{Y}_{305}$ is projected 305-day yield, Y_{DIM} is observed yield for the partial record, $\hat{Y}_D$ is the estimated daily yield for the remainder of the lactation, and DIM is days in milk for the partial record. Estimated average daily yield, for lactations < 155 days in length is calculated as:

$$\hat{Y}_D = [\hat{\alpha}_s + \hat{\beta}_s\,(\mathrm{DIM})]\,(Y_s) + [\hat{\alpha}_h + \hat{\beta}_h\,(\mathrm{DIM})]\,(\mathrm{HA})$$

where $\hat{\alpha}_s$ and $\hat{\beta}_s$ are intercept and slope constants for sample day yield (Y_s) and $\hat{\alpha}$ and $\hat{\beta}_h$ are intercept and slope for herd average milk yield (HA) divided by 1000. Thus the predictors of daily yield are sample day yield with an adjustment for DIM, and herd average milk yield with an adjustment for DIM (BASE variables). For DIM > 155, HA is replaced by the constant, 1, in estimating average daily yield.

The SCS variables considered as additional predictors were SCS of sample near day 20 (S20) and herd average SCS of sample near day 20 (SA20). Products of these variables with DIM and HA were also included. To estimate the future average daily milk yield for samples near day 20, the regression equation thus was:

$$\hat{Y}_D = \alpha + [\hat{\beta}_1 + \hat{\beta}_2\,(\mathrm{DIM})]\,(\mathrm{M20}) + [\hat{\beta}_3 + \hat{\beta}_4\,(\mathrm{DIM})]\,(\mathrm{HA}) + [\hat{\beta}_5 + \hat{\beta}_6\,(\mathrm{DIM}) + \hat{\beta}_7\,(\mathrm{HA})]\,(\mathrm{S20}) + [\hat{\beta}_8 + \hat{\beta}_9\,(\mathrm{DIM}) + \hat{\beta}_{10}\,(\mathrm{HA})]\,(\mathrm{SA20})$$

where α is the intercept and $\hat{\beta}$'s are the regression coefficients and M20 is the milk yield for sample near day 20.

Stepwise regression (SAS®, 1990) was used requiring F statistic ($p < .01$) for SCS variables to stay in the model. Separate analyses were run for four seasons and three parities, a total of 12 models. Number of observations used in these models are in table 1. Final models were run having BASE variables and selected SCS variables. In these models, if the product of any SCS variable with HA or DIM was selected initially, the corresponding SCS variable was also included.

Table 1. Number of observations used in analyses by parity and calving season

Season	Parity 1	Parity 2	Parity 3	Total
Winter	57,431	48,375	33,421	139,227
Spring	67,800	52,358	33,902	154,060
Summer	68,528	55,901	40,766	165,195
Fall	91,261	65,961	47,734	204,956
Total	285,020	222,595	155,823	663,438

RESULTS AND DISCUSSION

Means and standard deviations (SD) of sample day milk and protein yields by parity and season, and corresponding SCS values are in table 2. SCS averaged 2.78, 2.45, and 2.77 for the three parities, respectively. Standard deviations were 1.71, 1.83, and 1.96, respectively. The increase in the variance with advance in parity merely reflected fewer observations for later as compared to the earlier parities (table 1). Protein yield for samples near day 20 averaged 0.84 ± 0.15, 1.10 ± 0.20, and 1.15 ± 0.22 kg, respectively for the three parities. Increase in the protein yield with advancement in parity was due to increased milk yield (table 2). Increase in SCS with parity has earlier been reported (Kennedy et al., 1982; Wiggans and Shook, 1987; Schutz et al., 1990). At sample day 20 however, parity 2 had lower values as compared to first and third parites. Miller et al. (1996) also reported that SCS for the second sample day was 2.36 for first parity as compared to 2.32 for second parity cows.

Average daily protein for samples near day 20 by SCS and parity for fall season of calving are in figure 1. Trend were similar for the other seasons. Daily protein yield declined with increasing SCS which probably was due to the decline in milk volume. The decline was higher for later parities as compared with first parity. Second and third parities were more similar for these trends in contrast to first parity. Winter calvers had higher averages for both milk and protein yield as compared to cows calving in other seasons. Summer calvers were the poorest (table 2).

Earlier, Haenlein et al. (1968) reported a significant negative correlation of −.29 between Wisconsin Mastitis Test (WMT) score and total protein yield. Recently, also, most of the studies indicate decrease in total protein with increase in somatic cells of the milk (Monardes and Hayes, 1985; Schutz et al., 1990; Welper and Freeman, 1992). The changes that occur in total protein concentration reflect changes in concentration of the component parts. In general the caseins decline in concentration, and whey and serum proteins increase with infection; thus the overall effect on total protein can vary depending on the degree of infection (Sjaunja et al., 1984). Further, the infrared techniques used for protein estimation are influenced by the compositional changes in other constituents of milk (Sjaunja, 1984). The correlation

Table 2. Means and standard deviations of milk and protein yield (kg), and somatic cell score for samples near day 20

Parity	Season	Milk yield (kg)	Protein yield (kg)	Somatic cell score
1	Winter	26.5 ± 5.3	0.84 ± 0.15	2.79 ± 1.76
	Spring	26.3 ± 5.4	0.81 ± 0.15	2.85 ± 1.70
	Summer	25.3 ± 5.0	0.78 ± 0.14	2.88 ± 1.68
	Fall	25.7 ± 5.2	0.82 ± 0.15	2.61 ± 1.68
2	Winter	35.7 ± 7.0	1.14 ± 0.20	2.42 ± 1.85
	Spring	35.6 ± 7.0	1.12 ± 0.20	2.45 ± 1.84
	Summer	33.2 ± 6.5	1.03 ± 0.20	2.63 ± 1.84
	Fall	34.1 ± 6.7	1.09 ± 0.20	2.37 ± 1.79
3	Winter	37.6 ± 7.4	1.19 ± 0.22	2.72 ± 1.99
	Spring	37.1 ± 7.4	1.16 ± 0.22	2.78 ± 1.99
	Summer	34.8 ± 6.8	1.08 ± 0.20	2.96 ± 1.96
	Fall	36.2 ± 7.0	1.16 ± 0.21	2.69 ± 1.91

coefficient usually reported to show the association between protein percentage and somatic cells is also limited to linear association between the two variables. Differences in the models used, milk samples and populations studied, and different expressions of somatic cells used are some of the other reasons for differences among studies.

Estimates of predictors of average future daily protein yield from samples near day 20 are in table 3. The estimates are both from models without SCS variables (BASE variables only) and from models with BASE variables and SCS variables selected in the stepwise regression process. Only results from Fall season are presented; similar general conclusions can be drawn for other seasons of calving. Selection of SCS variables to predict average daily protein yield was not consistent across parities and seasons.

None of the SCS variables were selected in the model for first parity. For second and third parities, SCS on sample day and its product with DIM most frequently stayed in the model to predict future daily protein yield. Coefficients of determination (R^2) ranged from 51 to 61% for different models. Difference in R^2 between first and third parity was about 5 to 10% for predicting daily milk yield from samples near day 20. Inclusion of SCS in the prediction equations improved R^2 by less than 1%. Value

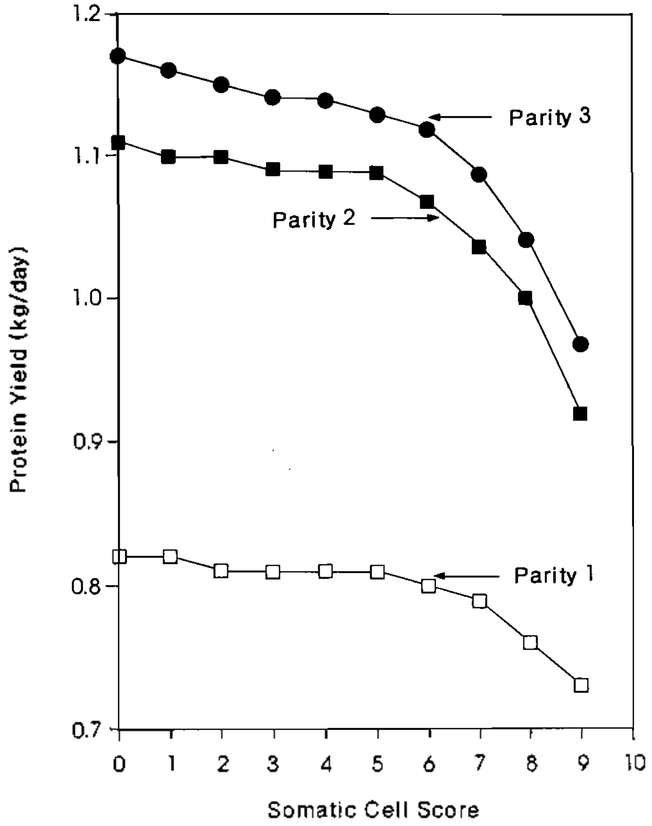

Figure 1. Average sample day protein yield near day 20 by SCS and parity for cows calving in fall season.

Table 3. Estimates of predictors of average daily protein yield (kg) in fall season of calving for samples near day 20 by parity

Parity	Variable[1]	Without SCS Variables		With SCS Variables	
		Estimate	SE	Estimate	SE
1	Intercept	−.0374	.0024		
	P20	.2355	.0052		
	P20 × DIM	.0054	.0002	*	
	HA	2.0963	.0161		
	HA × DIM	−.0081	.0007		
2	Intercept	.0059	.0034	.0095	.0035
	P20	.1499	.0056	.1501	.0056
	P20 × DIM	.0063	.0003	.0063	.0003
	HA	2.3342	.0239	2.3638	.0243
	HA × DIM	−.0139	.0010	−.0155	.0010
	S20			−.0046	.0006
	S20 × DIM			.0002	.0001
3	Intercept	.0246	.0042	.0299	.0044
	P20	.1110	.0064	.1109	.0064
	P20 × DIM	.0061	.0003	.0061	.0003
	HA	2.5442	.0288	2.5813	.0294
	HA × DIM	−.0153	.0012	−.0172	.0013
	S20			−.0052	.0007
	S20 × DIM			.0002	.0001

[1] Variables: P20 = Protein yield on sample near day 20; S20 = Somatic cell score on sample near day 20; HA = Herd average protein yield; DIM = Days in milk.

* Same as without Somatic Cell Score (SCS) variables.

of R^2 for cows calving in spring season were better (55.7 to 60.8%) as compared to the fall calvers (51.1 to 59.1%).

Regressions of average daily future protein yield on test-day yield, herd average protein yield and their interactions with DIM were not significantly different with or without SCS variables in the model (tables 3). Future daily protein yield was predictable to the same extent from samples near day 20 as would be milk yield (Khan et al., 1994). Herd average protein yield had higher correlation (.55 to .57) with future daily protein yield than sample day protein yield, for which correlation varied from .15 to .26. The values of regressions from this study are not comparable with the USDA factors for projecting protein yield because a different procedure is employed for such projections.

CONCLUSIONS

Somatic cell score was associated with sample day protein yield. A decrease in test day protein yield with increased SCS was observed for all seasons and parities. However, the association was not strong enough to improve the prediction of future yield when other expressions of yield were in the model. Selection of SCS variables as predictors of future daily protein yield was not consistent across seasons or parities. Improvement of R^2 was nominal when expressions of SCS were added to the usual prediction equations.

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