Herd and State Means for Somatic Cell Count from Dairy Herd Improvement

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ABSTRACT

To determine the impact of reducing the current legal limit of 750,000 cells/ml for somatic cell count (SCC) in US market milk, data were examined from 539,577 herd test days for Dairy Herd Improvement herds on test during 1996 and 1997. Somatic cell scores for individual cows were converted to SCC. The SCC for each cow was weighted by milk yield and used to compute herd mean on test day. The mean for each state was derived by weighting herd test-day SCC by herd test-day milk yield. State means were lowest in the West and highest in the Southeast. The percentage of herd test days with an SCC of >750,000 cells/ml ranged from 0 to 14% across states; the mean was 4%. Only 1% of the herd tests were >750,000 cells/ml on 2 consecutive test days. Mean SCC in the United States was 307,100 cells/ml for 1996 and 313,500 cells/ml for 1997. Mean SCC was lower during October through January (280,000 to 300,000 cells/ml) than during July and August (340,000 cells/ml). Herd size and SCC were negatively related; larger herds had lower SCC. Because records of some cows treated with antibiotics were included in the data, herd SCC means likely were higher than corresponding bulk tank SCC. Most herds had test-day SCC that were substantially below legal bulk tank limits and could have met lower limits (e.g., 500,000 cells/ml).
(**Key words:** milk quality, milk yield, somatic cell count, somatic cell score)

Abbreviation key: AIPL = Animal Improvement Programs Laboratory, **BTSCC** = bulk tank SCC.

INTRODUCTION

Milk SCC is a long-established barometer of milk quality (2). An elevated SCC is an indicator of udder infection (mastitis). To ensure a supply of high quality dairy products, bulk tank SCC (**BTSCC**) is monitored in milk shipments from producers. In 1993, the National Conference on Interstate Milk Shipments implemented a legal maximum of 750,000 cells/ml for BTSCC for Grade A producers (19). A shipment that exceeds this limit triggers a process by which a producer's milk may be excluded from the fluid market if the limit continues to be exceeded in subsequent tests (3, 19). In addition to legal requirements for BTSCC of market milk, most processors also pay a premium for milk with low BTSCC (10) or impose a deduction for milk with BTSCC above a threshold level. The primary basis for the premium quality payment is the negative relationship between SCC and casein composition (1), which impacts cheese yield. Also, high SCC have been shown to reduce the quality and shelf life of pasteurized fluid milk (8).

Of the developed countries, the United States has the most lenient SCC regulatory standards, which puts the image of the US industry at a disadvantage when marketing dairy products internationally. The legal maximum BTSCC is lower in other dairy exporting countries than in the United States (18). Canada has a limit of 500,000 cells/ml. In the European Community, Norway, Switzerland, Australia, and New Zealand, the maximum BTSCC is 400,000 cells/ml. In those countries, SCC is calculated as a geometric mean of successive milk shipments over several weeks; therefore, it is expected to be lower than an arithmetic mean (17).

The National Mastitis Council (12), the American Veterinary Medical Association, the American Association of Bovine Practitioners, and others (Anne Saeman, 1999, personal communication) have proposed that the legal maximum be reduced. No changes may be made in the Pasteurized Milk Ordinance without acceptance of a proposed change by the delegates at the National Conference on Interstate Milk Shipments followed by concurrence by the Food and Drug Administration. The National Mastitis Council (12) proposed adopting a 12-wk geometric mean calculation for producer BTSCC and to lower the regulatory limit in phases from 750,000 to 600,000, 500,000, and 400,000 cells/ml over a 4-yr period. However, the impact of such a change on producers has been difficult to quantify because comprehensive data on regional BTSCC are not readily available.

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Even national statistics on current BTSCC have not been calculated or reported.

Wells and Ott (20) reported BTSCC from 22 states based on five Federal Milk Marketing Orders during 1994 and 1995 and eight Federal Milk Marketing Orders during 1996. The 1996 orders represented about 37% of total US milk shipped from January through March. For all years, BTSCC was >350,000 cells/ml during winter and spring and peaked during July and August. Wells and Ott (20) indicated the vast majority of producers that were represented by the Federal Milk Marketing Orders had little difficulty in meeting the current BTSCC requirements. Similar results were reported by Ott et al. (12) for 1997 herd BTSCC (geometric means of BTSCC). Herd BTSCC peaked during August (336,700 cells/ml) and was lowest during November (257,000 cells/ml). Wells and Ott (20) and Ott et al. (12) reported a negative relationship between BTSCC and amount of milk shipped, which they also assumed would indicate a negative relationship between BTSCC and herd size.

An attractive alternative to SCC from DHI mastitis screening programs is SCS, which is derived directly from SCC by the formula SCC = $\log_2$(SCC/100,000) + 3. The transformation of SCC of composite milk into scores from 0.0 to 9.9 was adopted by DHI partially because of its simplicity and desirable statistical properties, such as near normality (14). Although records from cows treated with antibiotics and those with high SCS are included in DHI data, milk from treated cows and some high SCC cows would not go into the bulk tank. Therefore, a herd SCC mean calculated from converted SCS from cows on DHI test would probably be higher than the herd BTSCC for the same milkings. However, herds that participate in DHI mastitis screening might be expected to have lower mean herd SCC than nonparticipating herds because participation should help provide better overall management. Thus, mean SCC calculated from DHI herds could be either higher or lower than mean BTSCC of all herds that ship milk, and the distribution of herds for SCC level could also differ. Data from DHI may more accurately represent actual BTSCC for individual milking or daily yields than the BTSCC reported in previous studies (12, 20) because those studies often averaged BTSCC from multiple milk collections or even for an entire month.

The objectives of this study were to use SCS data from DHI records 1) to calculate mean herd SCC for various regions of the United States, 2) to determine the frequency of herd test days with an SCC of >750,000 cells/ml and other proposed limits, 3) to examine seasonal fluctuation in SCC, and 4) to examine the relationship between herd size and SCC. If SCC from DHI testing can be used to help characterize the mean and distribution of BTSCC used in determining legal authority to sell milk, the consequence to producers of proposed changes to the legal maximum for BTSCC can be evaluated.

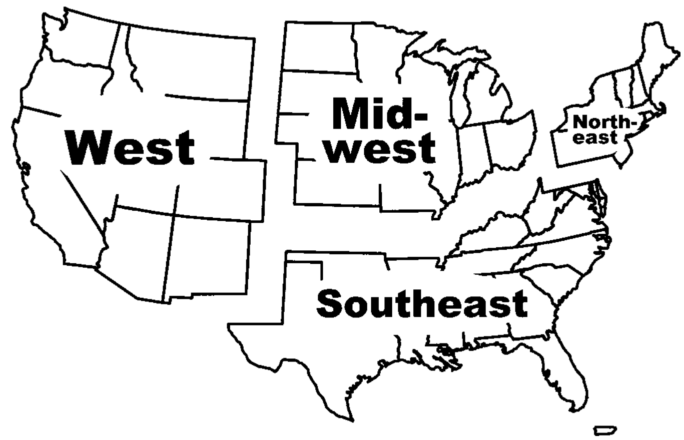

Figure 1. Definition of US regions.

MATERIALS AND METHODS

Test-day SCS data submitted to USDA Animal Improvement Programs Laboratory (**AIPL**) in Beltsville, MD, for cows on DHI test across the United States during 1996 and 1997 were used to estimate herd BTSCC. Information from records for cows with invalid identification or that failed other AIPL edit requirements (11) were not available to be included. Norman et al. (11) indicated what causes records to be rejected, but the most frequent reason is the sire is unreported. Meinert and Norman (9) reported that the percentage of records usable for genetic evaluating was 65% for 1988 through 1990. During 1996 and 1997, 48% of US herds were enrolled in DHI, and 85% of those herds participated in somatic cell testing (21, 23). All states and Puerto Rico were represented, but Alaska and Hawaii were not reported because of limited data. States were assigned to one of four regions: Northeast, Southeast, Midwest, and West (Figure 1).

To determine whether the mean SCS of cows with records that passed edits for genetic evaluations accurately represented the mean SCS of all cows on DHI test, we used records from 1 wk from AgSource Cooperative Services (Shawano, WI) were used to calculate the mean linear SCS for all cows (90,843), those cows with records that passed AIPL edits (50,667), and those cows with records that did not pass AIPL edits (40,176). Mean SCS were 2.80, 2.76, and 2.85, respectively, which indicated that SCS of cows with records that passed

Table 1. Equivalent values of SCS and SCC.[1]

SCS	SCC
	(cells/ml)
0	12,500
1	25,000
2	50,000
3	100,000
4	200,000
5	400,000
6	800,000
7	1,600,000
8	3,200,000
9	6,400,000

[1]$SCS = \log_2(SCC/100{,}000) + 3$; $SCC = 2^{(SCS - 3)}(100{,}000)$.

edits for national genetic evaluations were similar to those of other cows.

The SCS that AIPL receives from dairy records processing centers to calculate genetic evaluations for SCS (15) is a two-digit number that ranges from 0.0 to 9.9. The processing centers convert individual cow SCC to SCS. Individual cow test-day SCS from 3,349,186 lactations were converted back to test-day SCC in cells per milliliter by the formula: $SCC = 2^{(SCS - 3)}(100{,}000)$. The equivalent values of SCS and SCC are shown in Table 1. This double conversion led to some loss of precision on an individual cow basis because of rounding but should have little impact on means for herds and states.

Means for each herd test day were calculated from test-day SCC from individual cows. Thus, some herds had as many as 24 test days included for the 2 yr. To approximate herd test-day BTSCC, SCC from each cow was weighted by test-day milk yield. Herd means of SCC are not normally distributed but are less skewed than SCC of individual cows (17). Herd test days with information from <10 cows were excluded. Data for 539,577 herd test days remained.

The following statistics were calculated: 1) mean daily milk yield by state (each herd test day was weighted by number of cows); 2) mean SCC by state (each herd test day was weighted by number of cows and mean herd milk yield); 3) the percentage of herd test days with SCC of >750,000, >600,000, >500,000, or >400,000 cells/ml; 4) percentage of herd test days that exceeded those SCC levels on any two consecutive tests; and 5) national and regional mean SCC by year and month of test (weighted by number of cows and mean herd milk yield). Regional means for test-day milk and SCC were derived from herd test-day means. Herd test days were weighted by the number of cows to calculate mean milk yield on test day and by the number of cows and yield to calculate mean SCC on test day. This procedure should provide a reasonable approximation of SCC in the total milk produced from DHI herds in each region.

Multiple regression was used to calculate the linear and quadratic effects of herd test-day SCC on the number of cows per herd (remaining after edits) on test day within state, year, and month of test. Regressions were examined for the United States, the four regions, and the six states with the most cows per herd on test day.

RESULTS AND DISCUSSION

Table 2 shows the number of herd test days and DHI herd means for daily milk yield and SCC for the four regions and the United States for January 1996 through December 1997. The number of herd test days ranged from 41,693 for the West to 289,990 for the Midwest. Regional means for test-day milk ranged from 28.1 kg for the Southeast to 32.4 kg for the West. Regional means for test-day SCC ranged from 271,000 cells/ml for the West to 370,000 cells/ml for the Southeast. Regional mean SCC for the Northeast and Midwest were intermediate at 314,000 and 320,000 cells/ml, respectively.

Table 3 presents herd test-day means for milk yield and SCC for individual states during 1996 and 1997. The number of herd test days ranged from 86 for Wyoming to 103,392 for Wisconsin. Number of cows per herd on test day [remaining after AIPL edits (11)] was about 60% of the number of cow-years per herd reported by Wiggans for the United States (22, 24). State test-day means ranged from 19.1 kg for Puerto Rico to 35.0 kg for Colorado for milk yield and from 243,000 cells/ml for New Mexico to 457,000 cells/ml for Louisiana for SCC.

The percentages of herd test days with SCC of >750,000 cells/ml for individual states ranged from 0% for New Mexico and Wyoming to 14% for Tennessee. Indiana, Louisiana, and Puerto Rico also had >12% of herd test days with an SCC of >750,000 cells/ml. Although climatic conditions (temperature and humidity) are suspected to contribute to differences in SCC among states, different mean SCC for states that border each other were substantial (e.g., 6% for Kentucky vs. 14% for Tennessee, 2% for Michigan vs. 13% for Indiana, 8% for Mississippi vs. 13% for Louisiana). Therefore, mastitis control programs also have an important effect.

Table 2. Numbers of herd test days and herd test-day means for DHI milk yield and SCC by region of the United States during 1996 and 1997.

Region	Herd test days	Daily milk yield, $\overline{X}$	SCC, $\overline{X}$
	(no.)	(kg)	(1000 cells/ml)
Northeast	152,431	29.9	314
Midwest	289,990	30.0	320
Southeast	55,463	28.1	370
West	41,693	32.4	271
United States	539,577	30.4	310

Table 3. Herd test-day characteristics for DHI milkyield and SCC by region of the United States during 1996 and 1997.

Region	State	Herd test days	Cows per herd	Daily milk yield, $\overline{X}$	SCC, $\overline{X}$	Herd test days above SCC limits 750,000 cells/ml	600,000 cells/ml	500,000 cells/ml	400,000 cells/ml
		(no.)	(no.)	(kg)	(1000's)	(%)	(%)	(%)	(%)
Northeast	Connecticut	2061	64.3	30.9	293	2.0	6.0	11.4	21.4
	Maine	3153	44.4	29.8	266	2.6	5.2	9.9	18.8
	Massachusetts	2348	48.8	29.5	316	4.6	9.8	16.4	28.2
	New Hampshire	2209	52.9	31.7	283	2.0	6.0	11.9	21.1
	New Jersey	1915	46.8	29.3	349	7.6	14.5	22.4	36.3
	New York	50,161	50.9	30.3	300	2.9	7.1	13.3	25.0
	Pennsylvania	80.307	35.8	29.6	331	3.8	9.3	16.8	29.6
	Rhode Island	126	31.9	29.5	250	0.8	3.2	4.8	11.9
	Vermont	10,151	44.6	28.8	311	3.6	8.0	13.9	24.5
Midwest	Illinois	13,686	40.3	29.2	336	4.6	10.7	18.3	32.0
	Indiana	7692	35.6	28.4	436	12.7	21.9	31.9	45.6
	Iowa	25,120	34.0	29.3	334	5.4	11.4	18.9	31.6
	Kansas	7059	41.4	28.6	403	9.5	18.6	28.6	43.5
	Michigan	18,410	54.7	31.7	273	2.2	5.4	10.5	19.5
	Minnesota	72,583	36.1	29.8	334	5.3	11.6	19.6	32.5
	Missouri	8513	41.4	26.9	366	7.7	14.8	22.9	35.2
	Nebraska	5130	44.3	29.4	381	9.5	15.9	23.7	37.0
	North Dakota	1536	38.0	27.9	351	6.2	11.9	20.8	34.7
	Ohio	22,758	44.9	29.1	343	5.8	12.5	20.4	33.3
	Southeast Dakota	4111	37.5	28.5	405	9.9	17.8	26.3	39.7
	Wisconsin	103,392	36.6	29.0	288	2.8	6.5	11.9	21.7
Southeast	Alabama	1263	78.6	24.5	389	7.5	16.5	27.6	44.9
	Arkansas	1134	42.4	24.5	375	7.1	13.1	23.1	36.9
	Delaware	611	75.3	30.3	358	2.8	9.3	18.2	34.2
	Florida	477	185.2	30.5	404	8.8	21.8	35.4	58.1
	Georgia	2796	71.0	28.2	370	5.6	12.5	22.7	40.7
	Kentucky	4601	40.2	26.3	363	6.2	13.6	22.9	37.5
	Louisiana	1869	52.9	23.9	457	12.8	25.6	39.1	56.9
	Maryland	9332	49.4	29.0	363	6.0	13.2	22.6	37.3
	Mississippi	1582	69.0	26.5	425	8.3	19.2	31.9	50.6
	North Carolina	4741	67.2	28.8	377	6.6	14.5	24.8	42.0
	Oklahoma	2009	49.5	28.1	362	6.1	11.9	19.6	31.8
	Puerto Rico	934	53.1	19.1	420	12.3	24.3	38.9	55.5
	Southeast Carolina	1839	85.9	26.5	362	5.5	11.9	21.6	36.8
	Tennessee	5146	53.9	27.3	454	14.2	25.5	37.8	54.6
	Texas	4111	108.8	29.4	309	2.4	6.3	12.6	25.7
	Virginia	11,256	63.5	29.2	357	4.6	11.4	20.8	36.3
	West Virginia	1762	55.5	27.3	366	6.4	13.3	21.6	36.5
West	Arizona	793	422.3	32.2	297	1.5	3.8	6.4	16.4
	California	19,853	260.1	32.3	269	2.5	5.4	9.5	18.2
	Colorado	1302	130.1	35.0	250	1.4	3.1	6.7	13.2
	Idaho	4191	89.6	31.7	281	3.4	6.4	10.8	20.1
	Montana	1061	56.2	30.7	277	3.2	6.3	10.9	19.8
	Nevada	414	175.7	30.8	285	3.4	6.5	11.1	19.8
	New Mexico	422	227.8	32.9	243	0.0	1.7	5.5	12.8
	Oregon	4520	91.7	31.2	284	2.3	5.2	9.4	18.1
	Utah	4053	71.2	31.3	278	2.4	5.5	10.0	19.3
	Washington	4998	122.7	33.7	263	1.1	2.8	5.9	12.2
	Wyoming	86	47.6	30.1	277	0.0	8.1	11.6	18.6

The percentage of herd test days with SCC of >750,000, >600,000, >500,000, and >400,000 cells/ml are shown in Table 4 by region. Those >750,000 averaged 4% for the United States and ranged from 2% for the West to 7% for the Southeast. If the percentages based on DHI data are representative for BTSCC, the proposed decreases to the SCC limit would affect a large number of herds in those states with the highest mean SCC. Nationwide, 10, 17, and 29% of herd test days, respectively, had SCC that exceeded the lower SCC limits of 600,000, 500,000 and 400,000 cells/ml. The West had only 5, 9, and 18% of herd test days, respectively, that exceeded the lower SCC limits. In contrast, the Southeast had 14, 24, and 40% of herd test days, respectively, above the proposed maximums.

Bulk pickups for some farms represent yield from more than a single day. Less variation between herd BTSCC would be expected when more milkings are in

Table 4. Percentages of herd test days with SCC above various limits by region of the United States during 1996 and 1997.

Region	SCC limit 750,000 cells/ml	600,000 cells/ml	500,000 cells/ml	400,000 cells/ml
	(%)			
Northeast	4	8	15	27
Midwest	5	10	17	29
Southeast	7	14	24	40
West	2	5	9	18
United States	4	10	17	29

the bulk tank. However, a reduction in the SCC limit to 400,000 cells/ml would cause some upheaval in the industry, particularly for those herds and regions with the highest SCC.

Knowing the likelihood of having consecutive tests that exceed the SCC limit could be useful because herds are excluded for repeated violations and not for a single high BTSCC. Table 5 shows that consecutive pairs of test-day SCC of >750,000 cells/ml was 1% nationwide. This percentage increased to 4, 8, and 17 as the SCC limit was lowered to 600,000, 500,000, and 400,000 cells/ml, respectively. The likelihood that a consecutive pair of test-day SCC exceeded the limit at >750,000 cells/ml was low for all regions (1 to 2%) but became greater as the limit was lowered: 10 to 27% when the limit was 400,000 cells/ml.

Dairy producers need to be more concerned about persistently high BTSCC than about a high BTSCC from a single milk collection. Table 6 shows the percentage of herds with a high SCC on 1, 2, 3, or 4 or more consecutive test days after the incidence of a high SCC. For a SCC limit of >750,000 cells/ml, 76% of herds that exceeded that limit once did not exceed it on the following test day; however, 15, 5, 2, and 2% of herds did exceed that limit on 1, 2, 3, and 4 or more consecutive subsequent test days, respectively. As expected, the percentage of herds with consecutively high test-day SCC increased as the SCC limit was lowered. If the limit had been 400,000 cells/ml, 56% of herds with test-day SCC above that limit would not have exceeded it on the following test day; however, 17, 8, 5, and 14% of the herds would have exceeded the limit on 1, 2, 3, and 4 or more consecutive subsequent test days, respectively.

Table 5. Percentages of herd test days with SCC above various SCC limits on consecutive test days by region of the United States during 1996 and 1997.

Region	SCC limit 750,000 cells/ml	600,000 cells/ml	500,000 cells/ml	400,000 cells/ml
	(%)			
Northeast	1	3	7	16
Midwest	2	4	8	17
Southeast	2	7	14	27
West	1	2	5	10
United States	1	4	8	17

Table 6. Percentages of herds with a high test-day SCC that exceeded the same SCC limit on consecutive test days during 1996 and 1997.

Number of consecutive test days on which SCC limit was exceeded	SCC limit 750,000 cells/ml	600,000 cells/ml	500,000 cells/ml	400,000 cells/ml
	(%)			
0[1]	76	70	64	56
1	15	16	17	17
2	5	6	8	8
3	2	3	4	5
≥4	2	5	8	14

[1]Herd exceeded SCC limit on a single test day, but the following test-day SCC did not exceed the same limit.

If the SCC ceiling were lowered, many herds would have some difficulty in consistently meeting market milk standards, at least initially. One herd had an SCC of >750,000 cells/ml for 22 of 24 test days. Some DHI herds included in the data may not be Grade A producers and, therefore, not subject to BTSCC standards. Even though DHI herds will test all cows for SCC, milk produced from high-SCC or mastitic cows is often withheld from the bulk tank. Although policies that cause some producers to discontinue dairying may raise sociological concerns, the improvement of the overall quality of the milk supply would be a positive development for producers in general. However, the recent proposal to lower the SCC limit (7) to 400,000 cells/ml in three stages was not adopted by the National Conference on Interstate Milk Shipments in 1999 (3).

Monthly herd means for test-day SCC (Figure 2) peaked in July and August and were lowest from October through January. Somatic cell counts are generally highest during the summer, which coincides with an increased incidence of clinical mastitis during the summer months (13), and lowest during the winter (4). Monthly herd means for test-day SCC from January through April were higher during 1997 than during 1996; however, herd means for November and December were slightly lower during 1997 than during 1996. The SCC means from DHI data are in agreement with those reported by Wells and Ott (20) for BTSCC from Federal Milk Marketing Order herds during 1994 through 1996. They also found seasonal and year effects; BTSCC were highest in summer and higher during 1994 and 1995 compared with 1996. Seasonal patterns are likely to differ among geographic regions as reported by Schutz et al. (16) using DHI SCS. Both

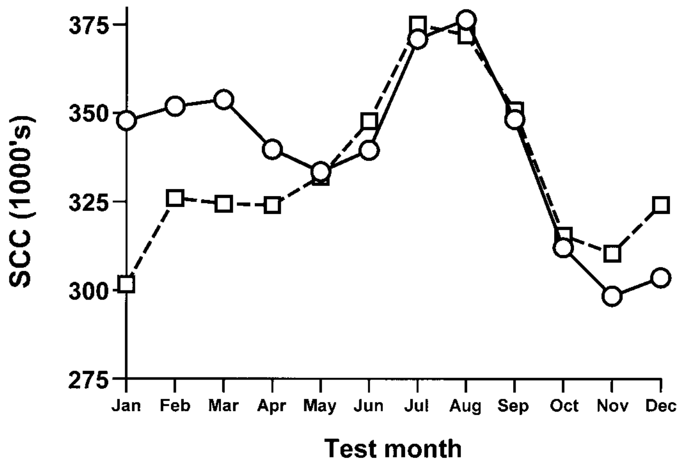

Figure 2. National means of test-day SCC during 1996 (□) and 1997 (○) by month on test.

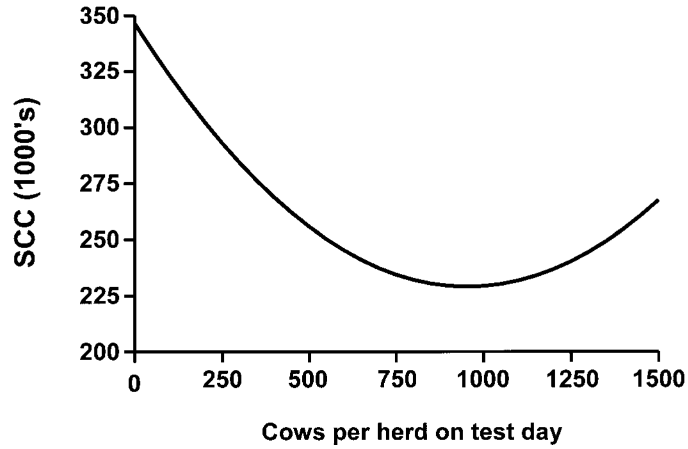

Figure 4. Relationship between SCC and number of cows per herd on test day for the six states (Arizona, California, Colorado, Florida, Nevada, and New Mexico) with the greatest mean number of cows per herd on test day.

seasonal and regional effects suggest a positive relationship between temperature and SCC. Both temperature and humidity affect SCC (5), but some evidence suggests that their impact on environmental conditions is more responsible for this than their impact on animal stress (13). However, neither temperature nor humidity data were available for direct examination in this study.

Curves for linear-quadratic regression of SCC on number of cows per herd on test day are in Figure 3 on a national basis. The predicted national curve is for 10 to 240 cows (2.5 standard deviations above the mean). Regional regressions are also shown, and all curves are calculated within state, year, and month of test. The number of cows per herd on test day was negatively associated with SCC, but quadratic terms were significant ($P < 0.01$) for all regions and for the United States. Larger herds generally had lower SCC than smaller herds, which supports the premise that mastitis management is better in larger herds than in smaller ones.

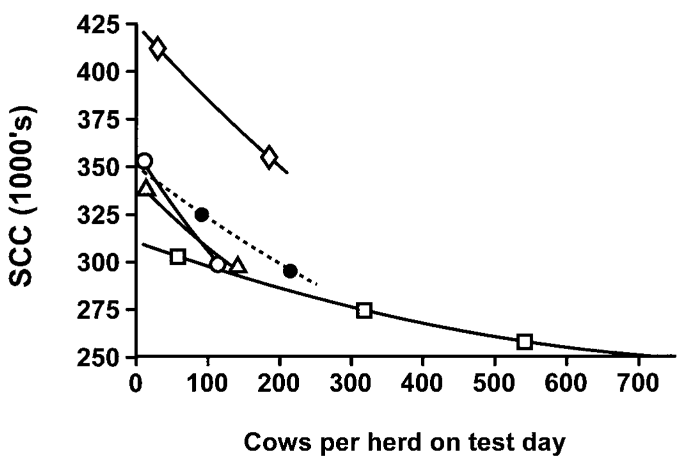

Figure 3. Relationship between SCC and number of cows per herd on test day for the Northeast (△), Midwest (○), Southeast (◇), West (□), and United States (●).

The regression curve for the six states with the most cows per herd on test day (Arizona, California, Colorado, Florida, Nevada, and New Mexico) is shown in Figure 4. The curve shows a decline in SCC as the number of cows per herd increases until around 1000 and then an increase in SCC as the number of cows per herd continues to increase. Figures 3 and 4 represent only the general relationship between SCC and number of cows per herd on test day. They cannot be used to determine the herd size at which SCC is minimized because actual herd size was not available because AIPL data edits rejected unusable cow records.

CONCLUSIONS

Regional differences in SCC were large. Herd test-day means for SCC were lowest in the West and highest in the Southeast. Year differences were present. Seasonal differences in herd means for test-day SCC were as expected; SCC were highest in summer and lowest in winter.

Meeting the SCC requirement of <750,000 cells/ml generally was not a problem for most herds. The frequency of herd test days with an SCC of >750,000 cells/ml was <5% for most states. For herds with a high SCC on test day, the high SCC level often was repeated on subsequent test days; 24% of herds with an SCC of >750,000 cells/ml exceeded that SCC level again on the following test day. Comparable figures for limits of >600,000, >500,000, and >400,000 cells/ml were 30, 36, and 44%, respectively. Greater efforts to improve milk quality are needed. If the dairy industry is unwilling to reduce the legal limit for SCC for Grade A milk, perhaps more emphasis should be placed on price incentives to reward the production of quality milk (similar to the differentials used for fat and protein). An improvement in milk quality would produce many benefits domestically and could provide additional benefit through more access to the international markets.

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